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SUMMARY OF TRANSPONDER DATA, JUNE 1975 THROUGH AUGUST 1976.(U)
JUN 77 G R HETRICH

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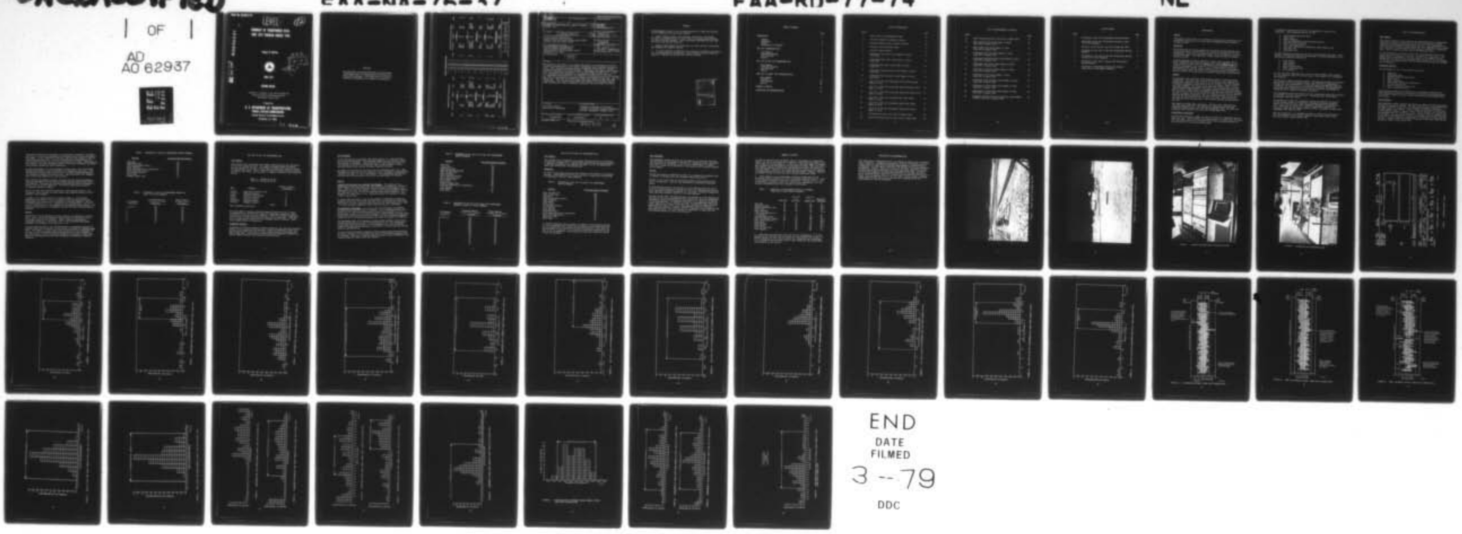

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SUMMARY OF TRANSPOND
JUNE 1975 THROUGH AUGU

George R. Hetrich

JUNE 1977

INTERIM REPORT

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National Technical Information
Springfield, Virginia 2215

Prepared for

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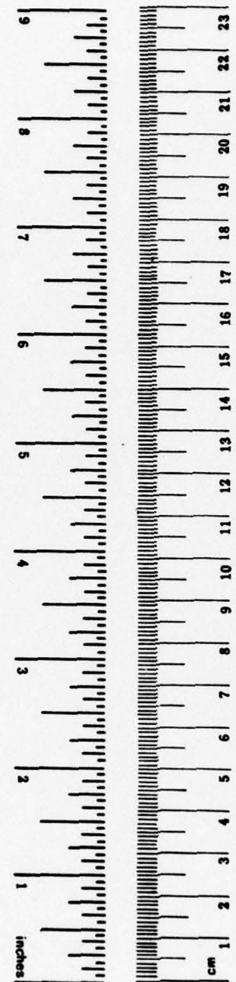
NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

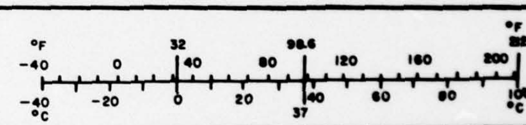
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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16. Abstract

The purpose of this report is to present the results of an evaluation on the performance characteristics of radar beacon transponders used in general aviation aircraft. Data collection was made possible through the utilization of a recently developed transponder performance analyzer. Transponder data samples were obtained over three time periods starting in June 1975 and ending in August 1976. A total of 87 transponders were measured for 9 parameters of operation in June 1975, 56 transponders were measured for 15 parameters of operation from July 1975 through May 1976, and 90 additional transponder samples were obtained during June, July, and August 1976. Data from new off-the-shelf units were compared to data from used transponders. Due to the relatively small data sample, no conclusions could be drawn regarding the overall transponder population, but some trends are evident.

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PREFACE

Acknowledgement is made to the following personnel for their participation in the transponder data collection efforts:

1. Messrs. Bernard Korsak, Harry Peterson, Fred Scisco, John Stanks, Van Mason, and Kenneth White for their roles in operating and maintaining the data collection equipment. Their involvement sometimes was under somewhat hectic and adverse conditions.

2. Messrs. George Mahnken and Vince Merel for their efforts in developing and debugging the computer software.

3. All other personnel at NAFEC who were indirectly involved in the project; e.g., providing special paraphernalia, signs, handbills, and the publicity required to expedite and promote the collection efforts.

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INTRODUCTION

PURPOSE.

The purpose of this report is to present the results of an evaluation on the performance characteristics of radar beacon transponders used in general aviation aircraft.

BACKGROUND.

The military and air carrier segments of the aviation field presently have their own methods for performing periodic checks on the operation of their transponders. They also issue reports which contain information relative to operational trends. This capability, however, does not exist for general aviation aircraft.

A report published by Lincoln Laboratory in April 1972 entitled, "Final Report Transponder Test Program," ATC-9, report number FAA-RD-72-30, contained initial information on the operational characteristics of general aviation transponders. The format of this National Aviation Facilities Experimental Center (NAFEC) report, however, is such that as measurements were periodically made, the results were compared with data previously collected to enable the determination of trends in operational characteristics.

GENERAL.

At the present time, NAFEC has three different modes for testing aircraft transponders. The first mode, known as the bench test mode, requires dismantling the transponder from the aircraft for testing. This mode measures transponder parameters in great detail, but by its nature, tends to be the most time consuming. The second is the ramp mode, which utilizes a mobile transponder performance analyser (TPA) which can be located near ramp taxiways to obtain a large number of transponder samples from itinerant aircraft. The third is the airborne rotating antenna mode, which can test many itinerant aircraft in flight, but has no control for transient effects such as distance variation and antenna shielding. The tests reported herein utilized the ramp mode of data collection for the bulk of the data. Some of the data were obtained using the bench mode. The airborne rotating antenna mode was not used.

This report is divided into three parts. The first part summarizes data collected during June 1975. The second part summarizes data collected during the 11-month period from July 1975 through May 1976. The third part summarizes data collected from June 1976 through August 1976.

DESCRIPTION OF EQUIPMENT.

A mobile TPA, developed at NAFEC, was used to obtain the transponder ramp and bench test data. This equipment was housed entirely in a mobile van, but could also have been connected to a flat-bed trailer with an antenna pedestal for data collection in the rotating antenna mode.

As originally configured, the TPA had the capability to measure nine parameters. These parameters were as follows:

1. Minimum Triggering Level (MTL),
2. Reply Power,
3. Reply Frequency,
4. Side Lobe Suppression (SLS) Decoding Accuracy,
5. Mode 3/A Decoding Accuracy,
6. Mode C Decoding Accuracy,
7. P_1/P_2 Ratio Required for Suppression Versus Signal Level,
8. Dead Time, and
9. Suppression Time.

The above capability existed for the data collected during June 1975. Subsequently, the equipment capability was expanded to include measurements on the following six additional parameters:

1. Pulse Width,
2. Pulse Spacing,
3. Pulse Jitter,
4. Mode 3/A Delay Time,
5. Mode C Delay Time, and
6. F1-F2 Spacing.

For the June 1975 transponder data, the first nine parameters were measured. For the transponder data in the later parts of this report, all 15 parameters were measured.

The TPA uses a computer software system to automatically control the amplitudes and spacings of the interrogation pulses, thus causing the transponder to exhibit its reply characteristics to many different interrogation conditions. In addition, an integral part of the software package was the development of subprograms which automatically controlled the collection, displaying, and storing of the 15 received transponder parameters.

The transponders tested were general aviation transponders which were installed in itinerant, privately owned aircraft. In addition, new off-the-shelf transponders were also tested.

The procedures followed for transponder testing are presented in section 2 of RTCA document number DO-150 entitled, "Minimum Performance Standards-Airborne Air Traffic Control (ATC) Transponder Equipment," dated March 17, 1972. These test procedures have received industry-wide approval and acceptance, which was the primary reason for their utilization in collecting transponder data using the TPA.

This data collection is an expanded follow-on to similar data collected in 1972 and summarized in the Lincoln Laboratory Final Report ATC-9, dated April 1972 (report number FAA-RD-72-30).

JUNE 1975 TRANSPONDER DATA

DATA SAMPLES.

This section contains a description of the measurements made on transponders installed in itinerant general aviation aircraft attending the Reading Operations and Maintenance Meeting during June 1975. The transponders were tested on a first-come-first-served basis and, with nonmandatory pilot cooperation, resulted in a random sample without regard to aircraft or transponder type. Figure 1 shows an overall view of the Reading Air Show.

Of the approximately 500 aircraft which were encountered during the 4-day period, about 170 taxied by the TPA van. Of these 170, there were 87 test samples made on transponders. The main reasons for the number of missed samples were (1) lack of pilot knowledge and/or interest in the test program, (2) one day of inclement weather, and (3) numerous aircraft were not equipped with transponders.

PARAMETERS MEASURED.

The following is a list of the parameters measured:

1. Dead Time,
2. Suppression Time,
3. Minimum Triggering Level (MTL),
4. Reply Power,
5. Reply Frequency,
6. P_2/P_1 Ratio Required for Suppression,
7. SLS Decoding Accuracy,
8. Mode 3/A Decoding Accuracy, and
9. Mode C Decoding Accuracy.

These nine measurements were compared with the standards established for these parameters as defined by the United States National Aviation Standard for the Mark X (SIF)/air traffic control radar beacon system (ATCRBS) characteristics.

TEST PROCEDURE.

The transponder testing equipment was housed in a mobile van which was parked adjacent to a departure taxiway. The test equipment used a horn antenna which was aimed across the taxiway so as to illuminate transponder antennas as aircraft taxied by for takeoff. Figure 2 shows the TPA setup in action next to the departure taxiway. Figures 3 and 4 show the inside of the TPA van and the equipment used for collecting the data. Figure 3 shows the computer rack in the center, the input/output terminal on the right, and the pulse mode generator plus an oscilloscope for monitoring the interrogation pulse spacing on the left. Figure 4 shows the transceiver chassis on the center right and the attenuator chassis on the center left.

Pilots were instructed via interphone to turn ON their transponder, to squawk code 7777, to taxi on the centerline of the taxiway, and to stop as directed by the flagman. At the completion of the test, the pilot was cleared to taxi and squawk the appropriate code. The entire procedure was accomplished as the pilot waited in the taxi line and took approximately 60 seconds. When requested, the results of the tests were given orally to the pilots; otherwise, the pilots were cordially thanked for their cooperation.

By using hand signals, the test personnel stationed next to the horn antenna stopped the aircraft as close as possible to a premeasured test point. Also, the aircraft was positioned to stop so that no aircraft appendages shadowed the transponder antenna from the test horn. The TPA horn has a 30° beamwidth which is more than adequate for this procedure.

This procedure was adopted to assure valid MTL and reply power measurements, since these parameters are affected by distance between antennas and intruding obstacles. The system was calibrated beforehand for direct measurement at either 6 feet or 50-foot separation. The 50-foot separation was used for the samples obtained at Reading.

Most of the data were obtained automatically under computer control. Two parameters, reply frequency and reply power, were measured manually by direct reading of test equipment.

A sample of the computer printout is shown in figure 5. The automatic measurements are shown as dots on the graphs, while the manually obtained measurements were entered into the computer via terminal keyboard. Each dot, or formated position for a dot, represented nine interrogations. The occurrence or nonoccurrence of a dot depended on the parameter being measured. This particular sample was for a transponder which met all nine of the performance standards.

RESULTS.

Comparisons of the measurements with the standards are summarized in tables 1 and 2. Table 1 lists the parameters measured versus the percentage of the transponders which met the standard. Table 2 shows the percentage of transponders which met at least some ("X") of the established performance standards. The parameter "X" varied from 1 to 9.

It can be seen from table 1 that the percentages of transponders meeting the standard varied from 94 percent for dead time to 39 percent for minimum-trigger level. From table 2, it can be seen that 100 percent of the transponders met at least 1 of the 9 standards, while 9 percent met all of the 9 standards. Data collected for five of the measured parameters (sensitivity, reply power, dead time, suppression time, and reply frequency) are depicted in figures 6 through 10.

TABLE 1. PERCENTAGE OF JUNE 1975 TRANSPONDERS MEETING STANDARD

Standard	Percentage Meeting Standard
Dead Time	94
Suppression Time	90
Mode 3/A Decoding Accuracy	89
Reply Frequency	89
P_2/P_1 Ratio Required for Suppression	82
Mode C Decoding Accuracy	81
SLS Decoding Accuracy	74
Reply Power	62
Minimum Trigger Level	39

TABLE 2. PERCENTAGE OF JUNE 1975 TRANSPONDERS MEETING AT LEAST "X" OF THE STANDARDS

"X" Standards out of 9	Percentage Meeting at least "X" of the 9 Standards	Number Meeting at least "X" of 9 Standards
1 out of 9	100	87
2	99	86
3	96	84
4	92	80
5	85	74
6	78	68
7	55	48
8	29	25
9	11	9

JULY 1975 TO MAY 1976 TRANSPONDER DATA

DATA SAMPLES.

This section covers transponder data samples obtained during the time period of July 1975 through May 1976. The samples collected during this period were all obtained at airports in the vicinity of NAFEC plus Teterboro Airport in northern New Jersey. Table 3 shows the airports visited during the period, the dates of the visits, and the number of samples collected at each respective airport.

TABLE 3. ITINERY OF TPA VAN
(July 1975 through May 1976)

Date	Location	Number of Samples Collected
12/2/75	Bader Field, Atlantic City	1
12/12/75	Hammonton Airport	7
1/6/76	Cape May County Airport	3
1/9/76	Millville Airport*	6
1/10/76	Millville Airport	9
1/26-30/76	Teterboro Airport	26
2/3-6/76	Teterboro Airport	4
	Total	56

*One Transponder Inoperative

The total number of samples collected during this period was 56, of which 26 represented the off-the-shelf supply of transponders stocked by a major distributor of aircraft parts and supplies. These off-the-shelf transponders were all from the same manufacturer and were all the same model. They were all in factory-sealed cartons and were presumably never in service. Their serial numbers were not consecutive.

PARAMETERS MEASURED.

In addition to the nine parameters measured during the June 1975 data collection effort, six new parameters were measured. These new parameters include F1-F2 spacing, pulse width, pulse jitter, pulse spacing, mode 3/A delay time, and mode C delay time. The ability to measure these new parameters resulted from further computer software development during this period.

TEST PROCEDURE.

The 26 off-the-shelf transponders were bench tested; i.e., they were hard-wired to the TPA equipment. The remaining samples were all obtained through the ramp mode of operation. Unlike the June 1975 test procedure, where aircraft taxied by the TPA van at departure time, it was necessary to drive the van to most of the aircraft in order to perform the tests.

The number of interrogations per data point was arbitrarily set at 50. This increased the total test time per sample for the 15 parameters to approximately 3 minutes from start to stop of measurement. This measurement time differed from the June 1975 measurement time, which was approximately 60 seconds.

RESULTS.

COMBINED OFF-THE-SHELF AND ITINERANT TRANSPONDERS. The results of the comparisons of the measurements with the standards are summarized in tables 4 and 5. Table 4 lists the parameters measured versus the percentage of the transponders which met the standard. Table 5 shows the percentage of transponders which met at least "X" of the established performance standards. The parameter "X" varied from 1 to 15. These two tables are analogous to tables 1 and 2, respectively.

It can be seen from table 4 that the percentage of transponders meeting the standards varied from 100 percent for dead time to 63 percent for reply power. From table 5, it can be seen that 100 percent of the transponders met at least 8 of the 15 parameter standards, while 13 percent met all 15 standards.

OFF-THE-SHELF TRANSPONDERS. As a group, the 26 off-the-shelf transponders performed better than the overall 56 samples. The 7 transponders which fell within all 15 of the specifications were from the off-the-shelf lot. All 26 units met at least 11 of the specifications. Ninety percent of these transponders were within specification on at least 13 of the 15 measured parameters. Graphs for six of the measured parameters are shown in figures 11 through 16.

The suppression time, F1-F2 spacing, and pulse width standards were the most frequent specifications not met by the distributor's lot. Six transponders did not meet these specifications. There appeared to be some correlation between F1-F2 spacing and pulse width, with three of the six boxes not meeting these two specifications.

Two of the 26 off-the-shelf transponders had excessive warmup times requiring at least 15 minutes of ON time before any type of credible measurements could be performed. There was no apparent physical damage to these transponders, and replies during the warmup period were sporadic.

TABLE 4. PERCENTAGE OF THE JULY 1975 TO MAY 1976 TRANSPONDERS MEETING STANDARD

Standard	Percentage Meeting Standard
Dead Time	100
Pulse Jitter	98
Suppression Time	96
Mode 3/A Decoding Accuracy	96
Mode 3/A Delay Time	95
Reply Frequency	93
Mode C Decoding Accuracy	93
SLS Decoding Accuracy	93
Mode C Delay Time	88
Pulse Width	86
Minimum Trigger Level	82
P_2/P_1 Ratio Required for Suppression	73
F1-F2 Spacing	72
Pulse Spacing	72
Reply Power	63

TABLE 5. PERCENTAGE OF THE JULY 1975 TO MAY 1976 TRANSPONDERS MEETING AT LEAST "X" OF THE STANDARDS

"X" Standards out of 15	Percentage Meeting at least "X" of the 15 Standards	Number Meeting at least "X" of the 15 Standards
1 out of 15	100	56
2	100	56
3	100	56
4	100	56
5	100	56
6	100	56
7	100	56
8	100	56
9	98	55
10	95	53
11	89	50
12	79	44
13	72	40
14	50	28
15	13	7

JUNE 1976 TO AUGUST 1976 TRANSPONDER DATA

DATA SAMPLES.

This section covers transponder data samples obtained during the time period of June 1976 to August 1976. The data were gathered from aircraft expositions in Reading, Pennsylvania, and Oshkosh, Wisconsin. In all, 90 samples were taken, with the majority from Pennsylvania.

PARAMETERS.

The same 15 transponder parameters were measured as discussed in the previous sections. These parameters are listed in table 6, along with the percentage of transponders which met these standards.

TABLE 6. PERCENTAGE OF JUNE 1976 TO AUGUST 1976 TRANSPONDERS MEETING STANDARD

Standard	Percentage Meeting Standard
Mode 3/A Delay Time	100
Mode C Delay Time	100
Dead Time	100
Mode 3/A Decoding Accuracy	98
Reply Frequency	98
Pulse Width	93
Pulse Jitter	91
SLS Decoding Accuracy	88
F1-F2 Spacing	86
Pulse Spacing	86
Suppression Time	85
P_2/P_1 Ratio Required for Suppression	85
Mode C Decoding Accuracy	79
Sensitivity (MTL)	66
Reply Power	55

It should be explained that the number of samples of each parameter varies; i.e., 90 transponders were checked for sensitivity and frequency while only 82 were checked for pulse spacing and SLS characteristics. The reason for this variation is that some of the aircraft moved before completion of the test on all 15 parameters. This premature movement was beyond the control of the test personnel.

TEST PROCEDURE.

The transponder testing procedure was the same for the June 1975 test data. The TPA mobile van was parked to the side of a departure taxiway, and pilots were instructed by interphone to turn ON their transponders, to squawk code 7777, to taxi on the centerline of the taxiway, and to stop as directed by the flagman.

RESULTS.

The raw data which are summarized in table 6 are presented in graphical form in figures 17 through 30 for all parameters except P_2/P_1 ratio.

Figures 17, 18, and 19 show the decoding accuracys for SLS, mode 3/A, and mode C, respectively. Each bar line represents an individual transponder sample.

For SLS decoding accuracy, the presence of a bar indicates the time span of the P1-P2 interrogating pulse spacing over which the transponder was successfully suppressed, despite the presence of a P3 pulse. Successful suppression means less than 10-percent replies to the interrogations.

For mode 3/A and mode C decoding accuracy, the presence of a bar indicates the time span of the P1-P3 interrogating pulse spacing over which the transponder successfully replied with 90-percent efficiency; i.e., replied to 90 percent of the interrogations. As compared with mode 3/A interrogations (figure 18), visual inspection of figure 19 indicates that a significant number of transponders did not reply to the mode C interrogations (altitude reporting). Even though the majority of general aviation transponders do not have altitude reporting capability, they are required, by regulation, to reply with the F1-F2 bracket pulses to a mode C interrogation.

SUMMARY OF RESULTS

In order to establish good confidence limits on the trends of a statistical sample, the size of the sample must represent a significant percentage of the total number of possible samples. In this case, the total number of transponders in operation is estimated to be approximately 100,000. The three sets of data samples combined, 87+56+90=233, represented less than 0.233 percent of the total sample. Therefore, no attempt was made to generalize the condition of transponders operating in the overall ATC environment. However, comparing the overall results of these data, the following trends were found:

1. There appears to be an improvement trend over earlier data in the percentages meeting standards for the 15 parameters measured (table 7). Nine of the parameters measured showed this improvement. This may be due to new certification requirements which have recently been implemented; i.e., all aircraft transponders must have a biannual certification.

TABLE 7. PERCENTAGE OF TRANSPONDERS MEETING THE STANDARD (THREE SETS OF DATA SAMPLES COMPARED)

	June 1975	July 1975 To May 1976	June 1976 To August 1976	Cumulative (Average)
Dead Time	94	100	100	98
Suppression Time	90	96	85	90.3
Minimum Triggering Level	39	82	66	62.3
Reply Power	62	63	55	60
Reply Frequency	89	93	98	93.3
P_2/P_1 Ratio Required for Suppression	82	73	85	80
SLS Decoding Accuracy	74	93	88	85
Mode 3/A Decoding Accuracy	89	96	98	93.3
Mode C Decoding Accuracy	81	93	79	84.3
Pulse Width	-	86	93	89.5
Pulse Spacing	-	72	86	84
Pulse Jitter	-	98	91	94.5
Mode 3/A Delay Time	-	88	100	94
F1-F2 Spacing	-	72	86	79

2. Reply power and sensitivity were the worst in performance. It is suspected, but not verified, that the reason for this condition may be due to a cabling situation in the aircraft between the transponder and the antenna; i.e., a connector may have been loose or cable losses may have caused these two parameters to show poorly.

CONCLUSIONS AND RECOMMENDATIONS

This evaluation of transponder data is too limited in sample size to establish clear conclusions. As mentioned previously, in order to establish good confidence limits, a significant percentage (approximately 10 percent) should be measured. For this report, less than 0.233 percent of the total population was measured. However, trends in the data can be noted, especially the differences between new off-the-shelf units and operational units. Projecting to the future, schedules of operational evaluation in the ramp test mode, such as reported herein, would be a valuable tool for monitoring the operable status of the transponder fleet in the air traffic control system. Changing trends caused by such items as new certification requirements and TSO requirements will then be determined.

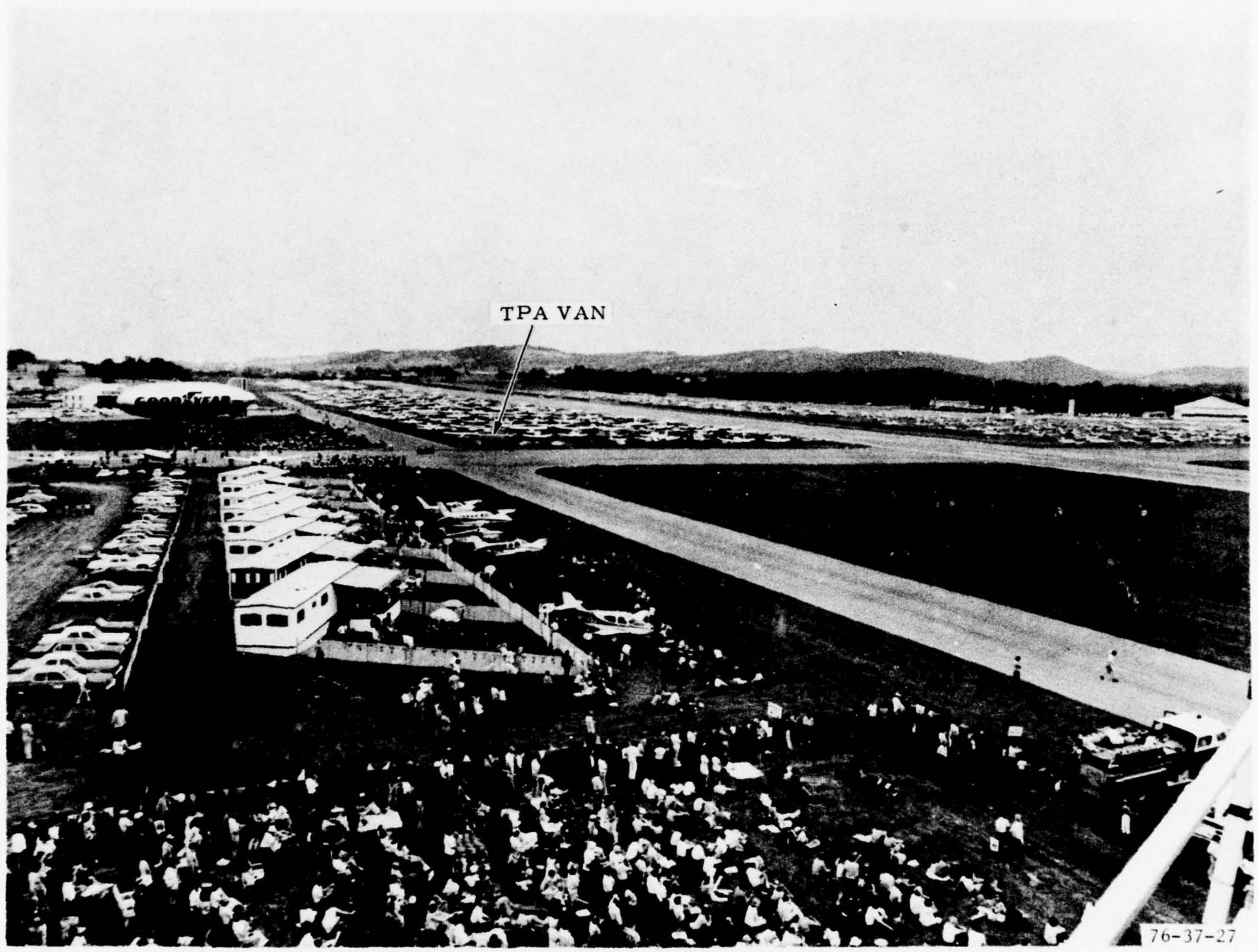


FIGURE 1. OVERALL VIEW OF THE READING AIR SHOW

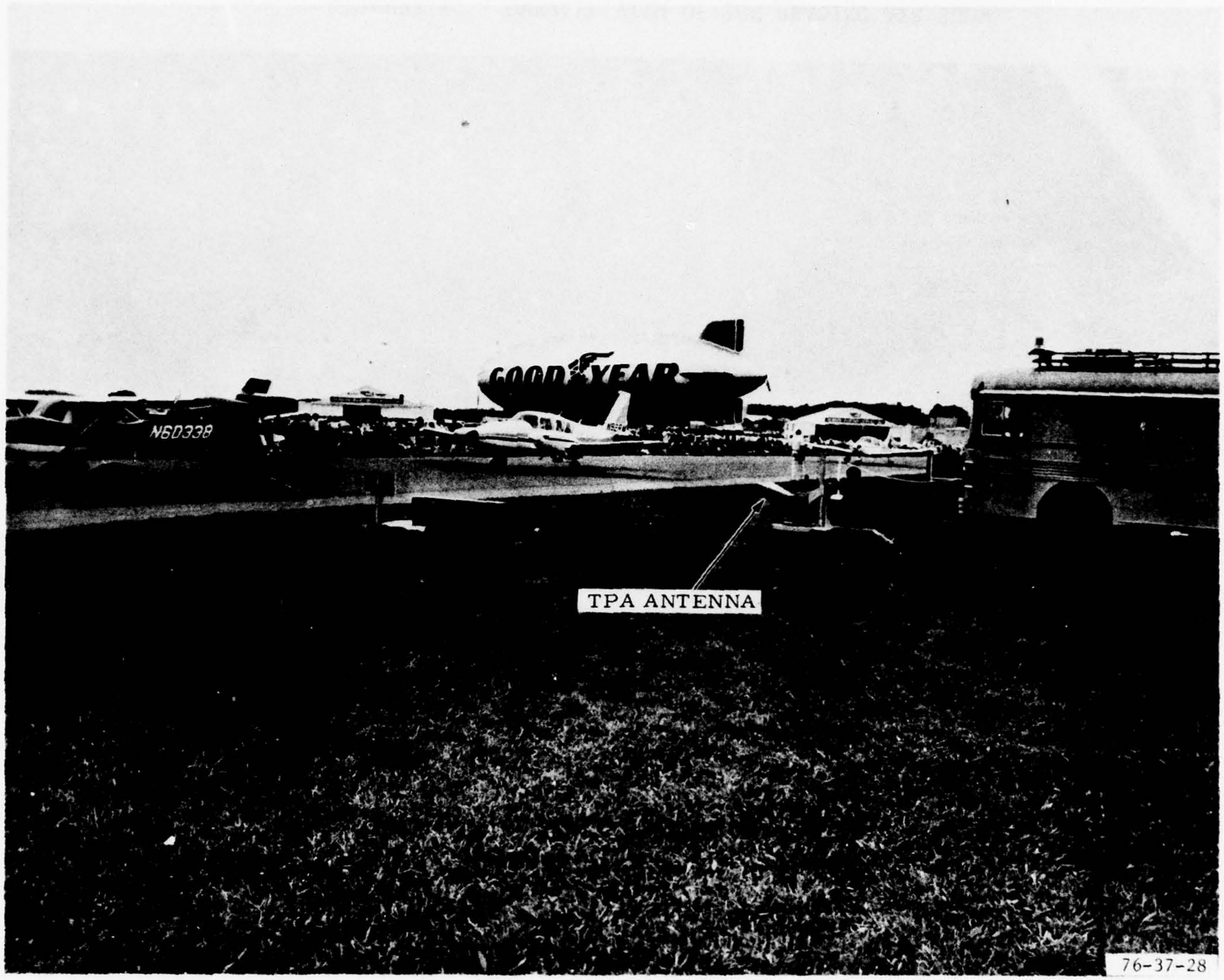


FIGURE 2.   TPA SETUP ADJACENT TO DEPARTURE TAXIWAY

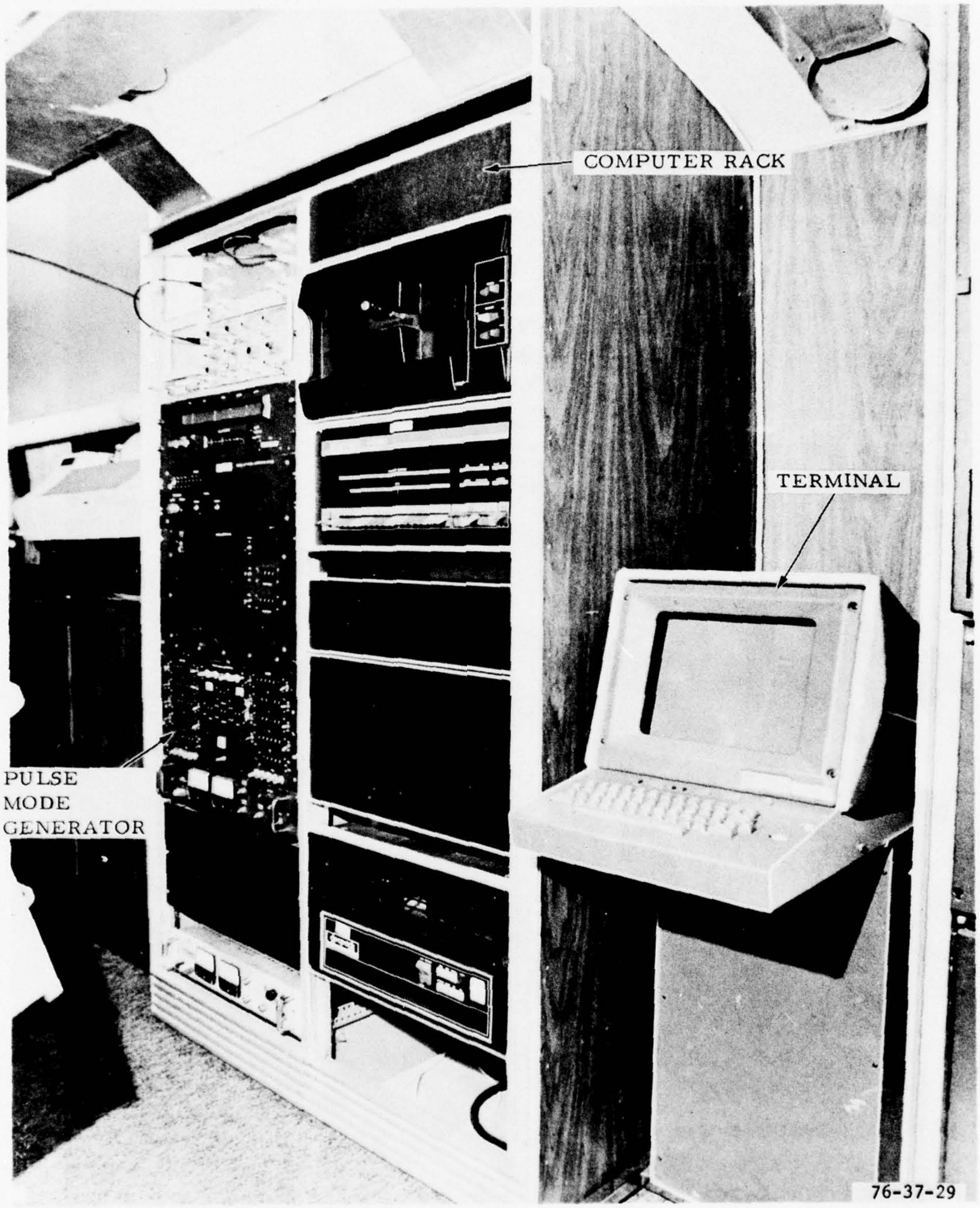


FIGURE 3. COMPUTER EQUIPMENT USED TO COLLECT TPA DATA

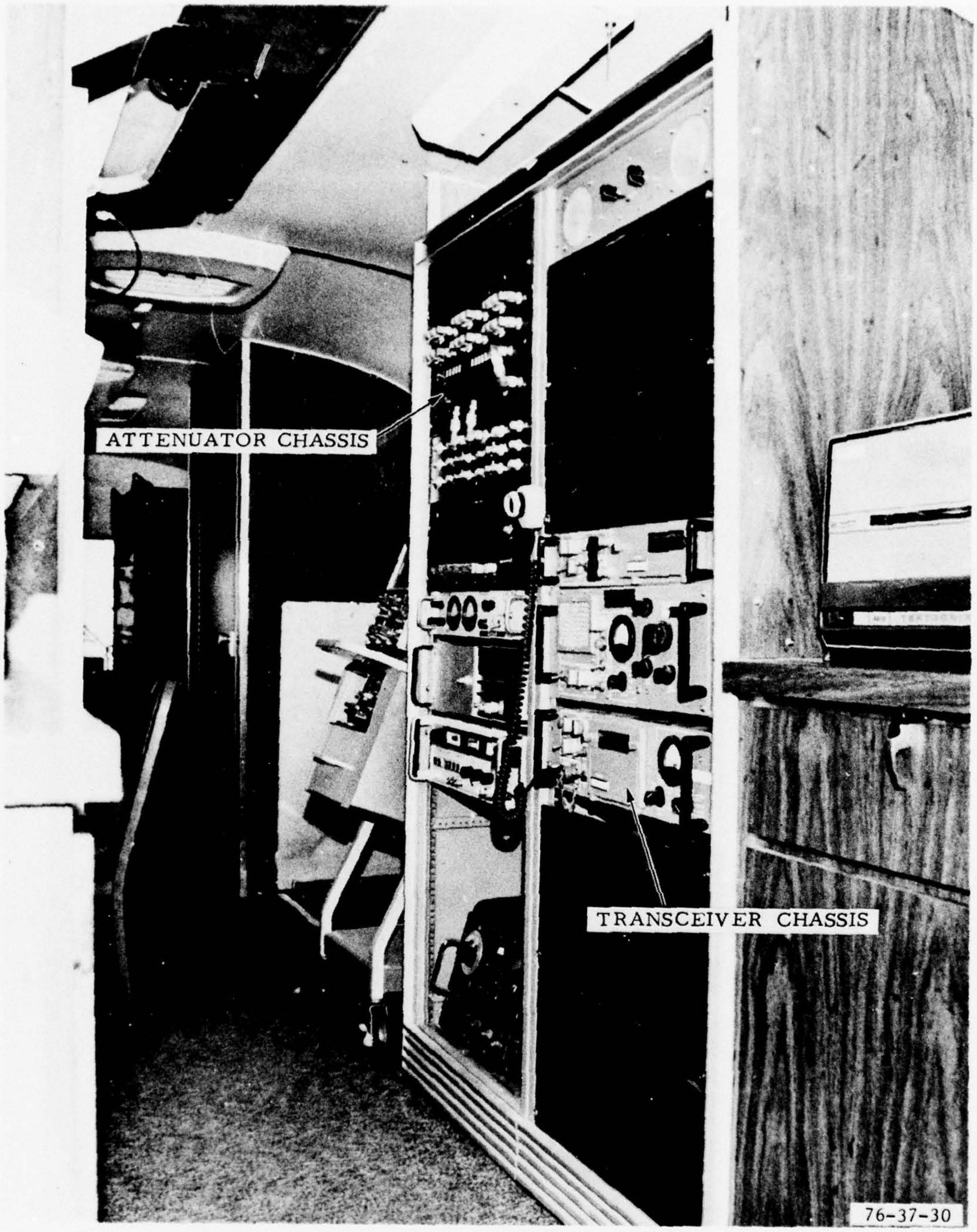
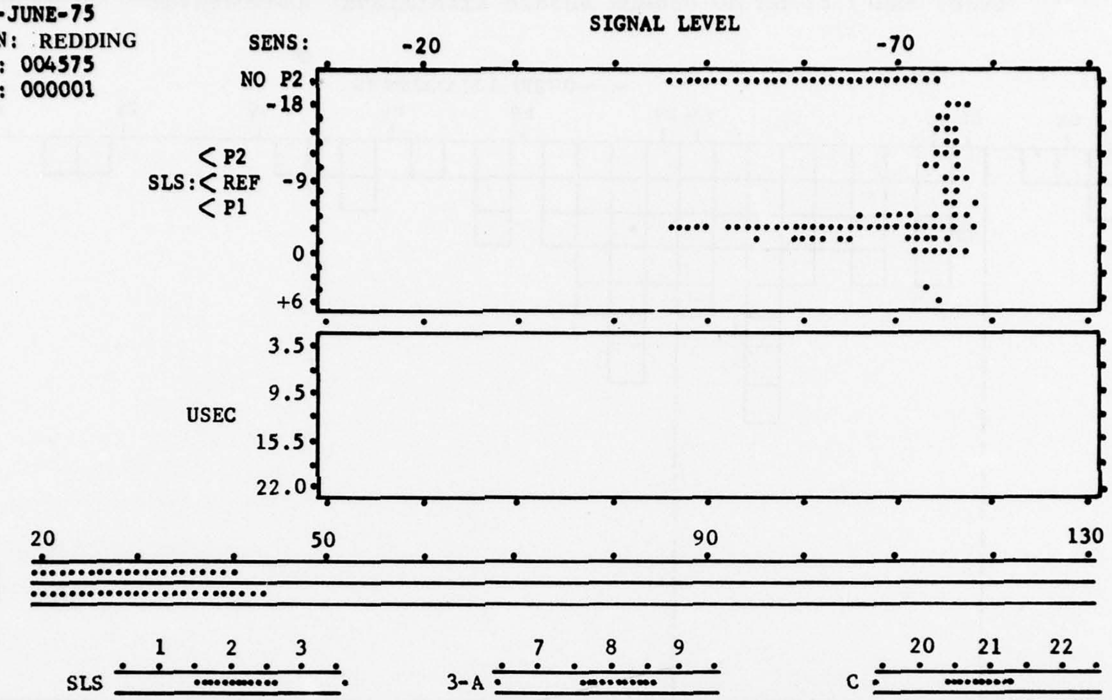


FIGURE 4. ATTENUATOR AND TRANSCEIVER RACKS

A-C ID. N56313	A-C TYPE	CODE: 7777	FREQ: 1090 MHZ
TEST NO. 27.0	XPNDR TYPE	ALT: 0	POWER DBM

DATE: 9-JUNE-75
LOCATION: REDDING
TAPE ID: 004575
FILE NO: 000001



F1-F2 SPACING: 20.27 USEC. WIDTH: 470 , 460 NS. PWR OUT: 41.3, 40.6 DBM
DELAY TIME: MODE 3-A: 3.10 USEC. MODE C: 2.85 USEC JITTER: 190 NSEC

AVERAGE CODE PULSE SPACING IN NANOSECONDS

	ACT		ACT		ACT		ACT		ACT		ACT
A1:	28500K	A2:	57200K	A4:	86300K	B1:	116100K	B2:	144200K	B4:	173300K
C1:	14000K	C2:	42900K	C4:	71600K	D1:	129800K	D2:	158800K	D4:	187700K

COMMENTS:

-------COURTESY OF NAFEC., ATLANTIC CITY, N.J.-------- 76-37-1

FIGURE 5. COMPUTER PRINTOUT SAMPLE

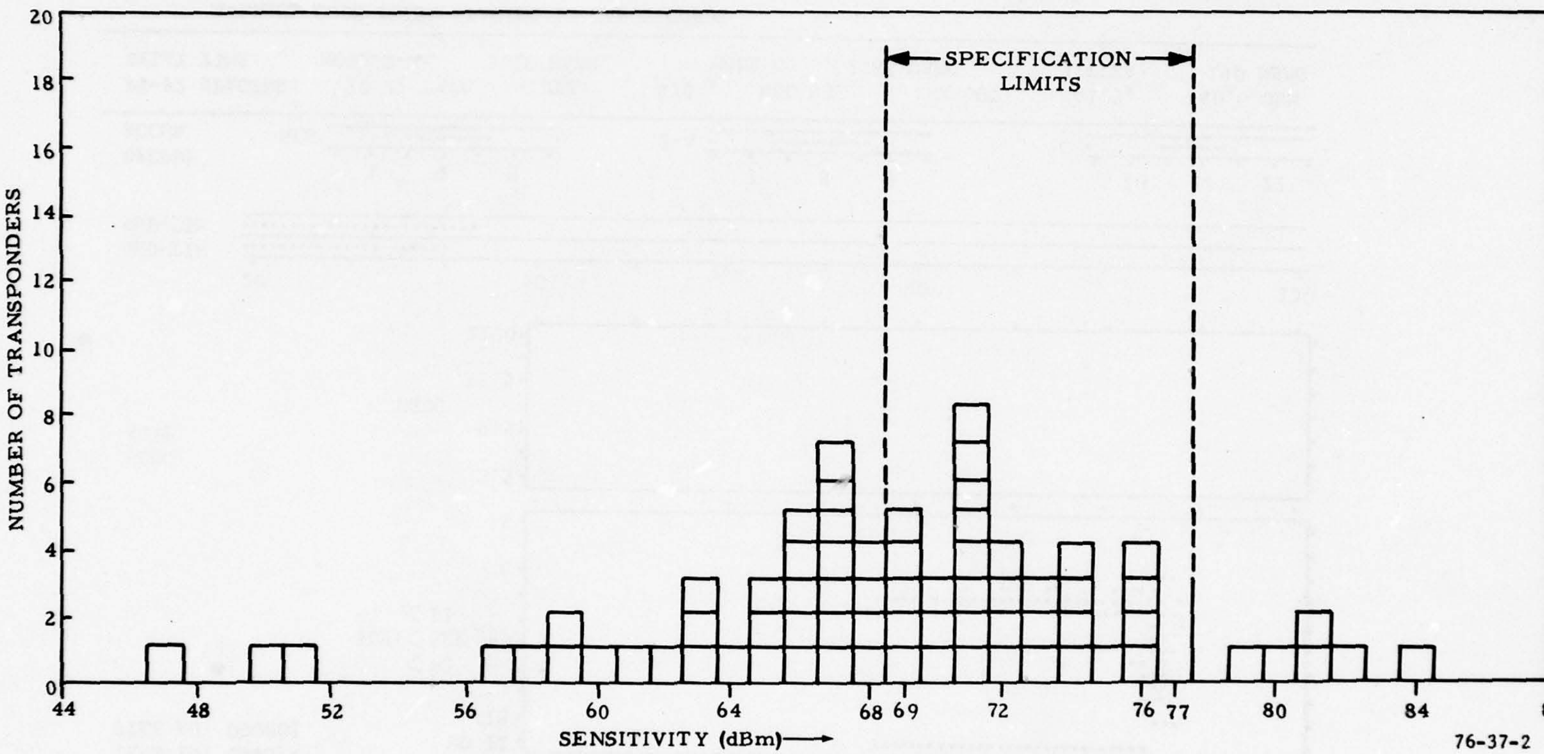


FIGURE 6. TRANSPONDER SENSITIVITY VERSUS NUMBER OF UNITS (JUNE 1975)

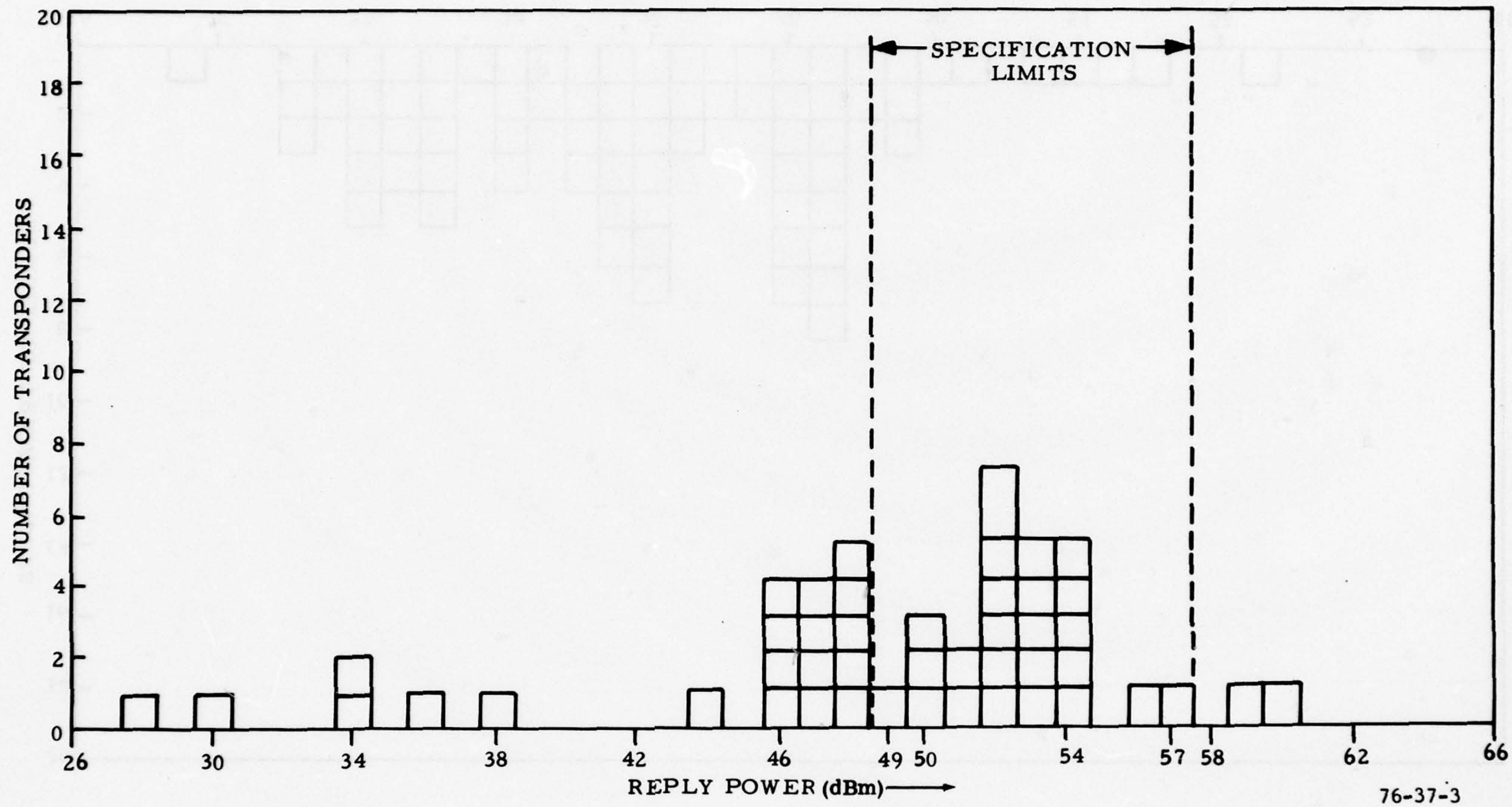


FIGURE 7. TRANSPONDER REPLY POWER VERSUS NUMBER OF UNITS (JUNE 1975)

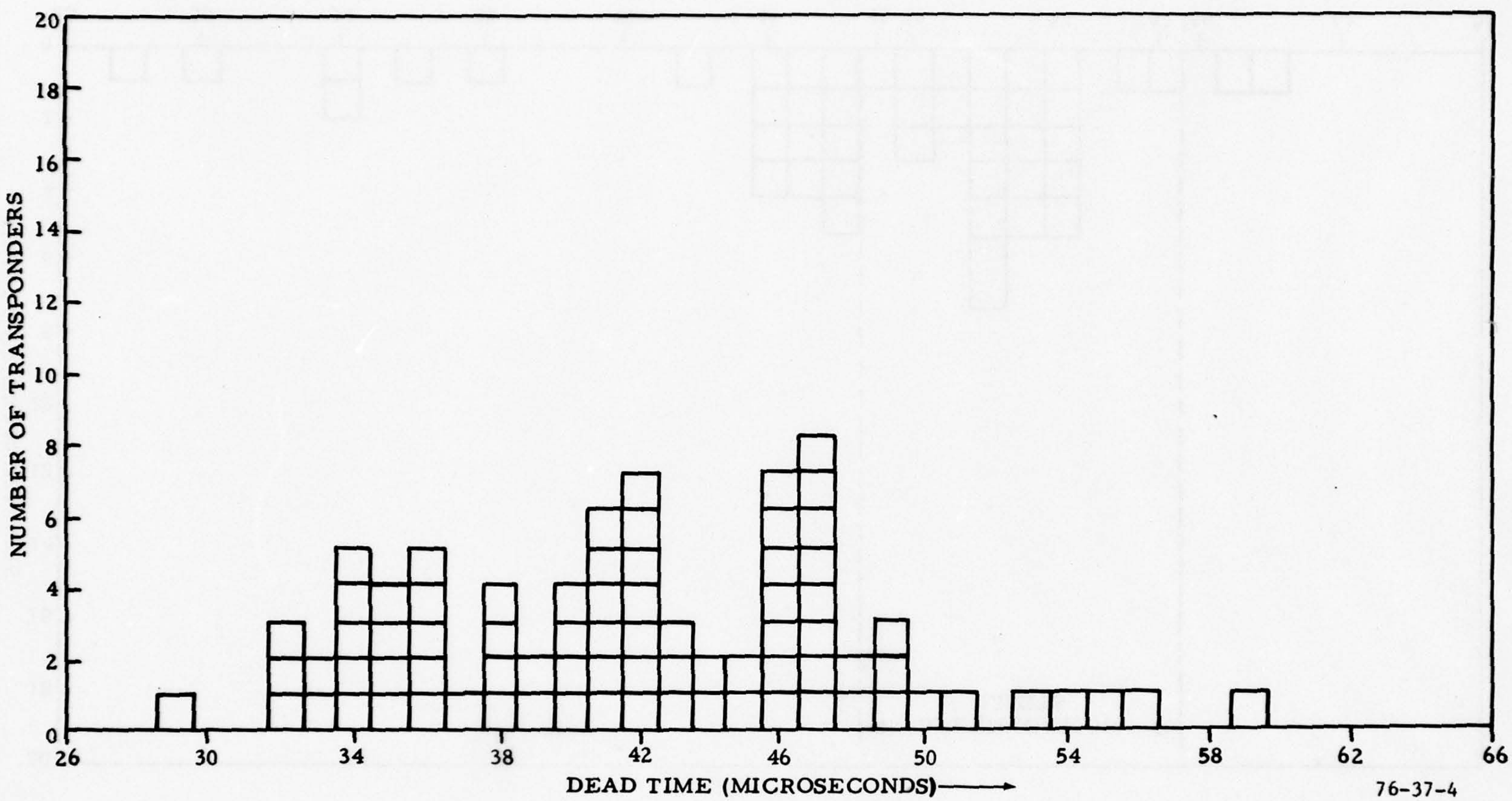


FIGURE 8. TRANSPONDER DEAD TIME VERSUS NUMBER OF UNITS (JUNE 1975)

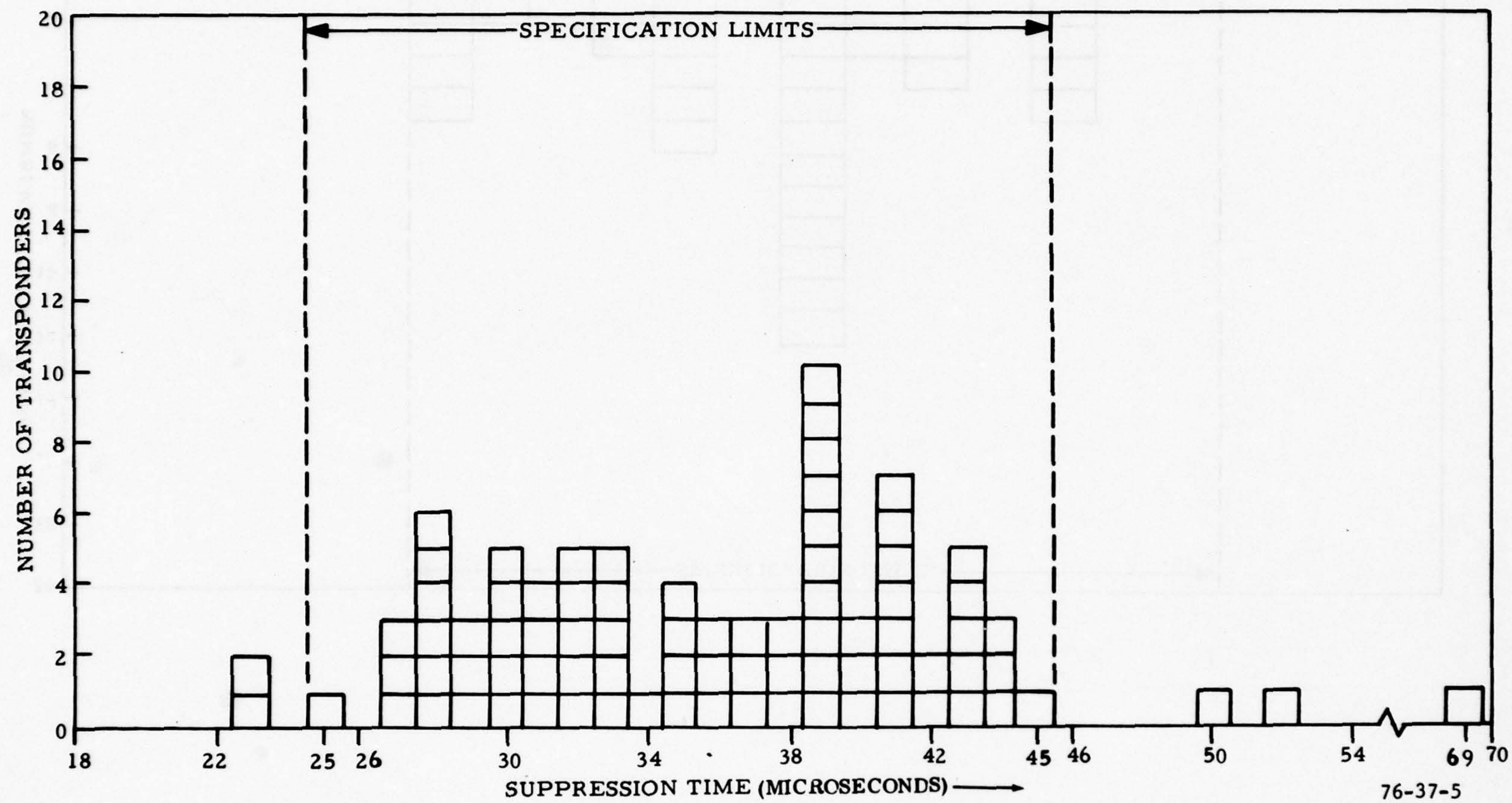


FIGURE 9. TRANSPONDER SUPPRESSION TIME VERSUS NUMBER OF UNITS (JUNE 1975)

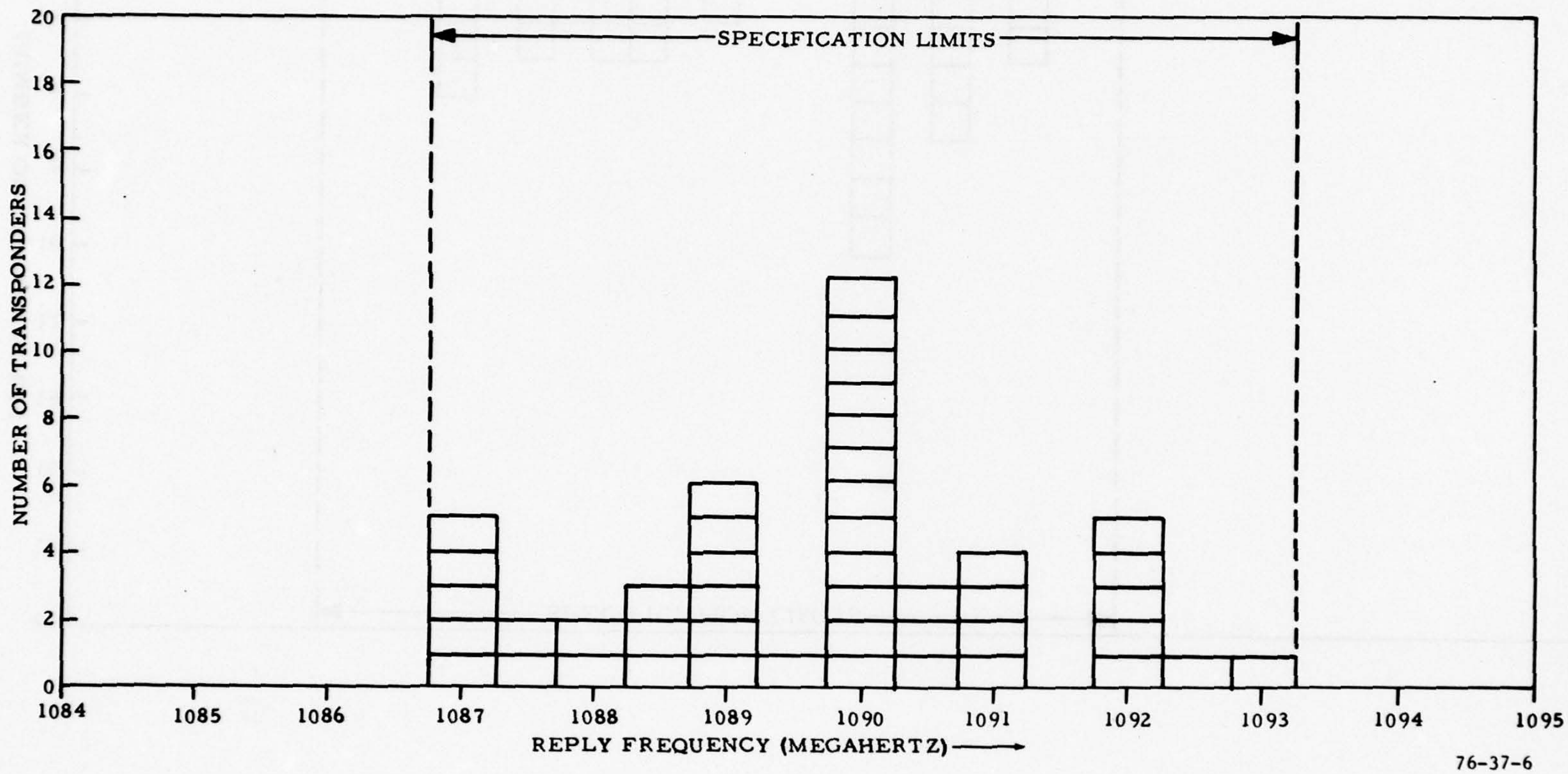


FIGURE 10. TRANSPONDER REPLY FREQUENCY VERSUS NUMBER OF UNITS (JUNE 1975)

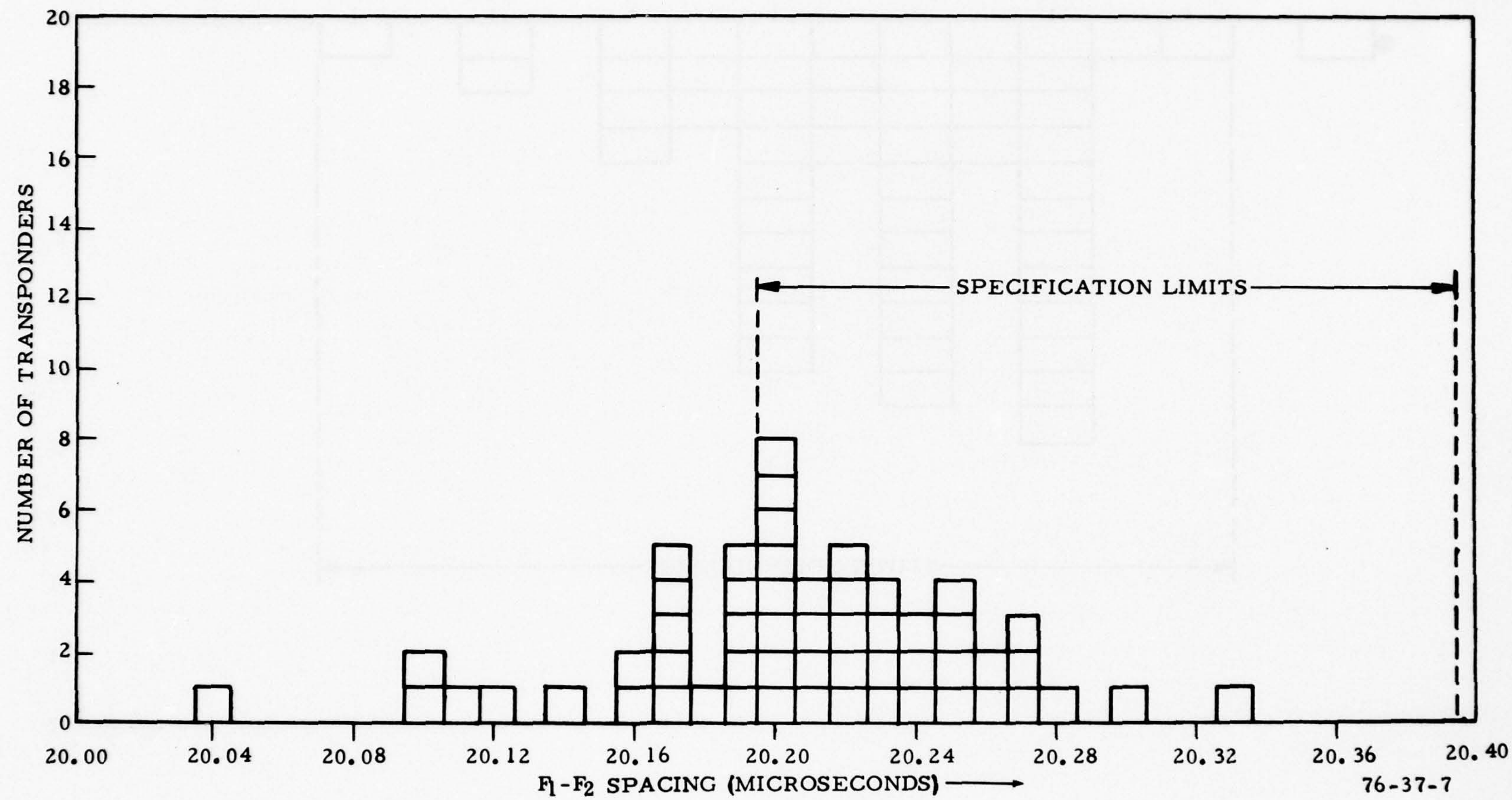


FIGURE 11. JULY 1975 TO MAY 1976 TRANSPONDER F1-F2 SPACING VERSUS NUMBER OF UNITS

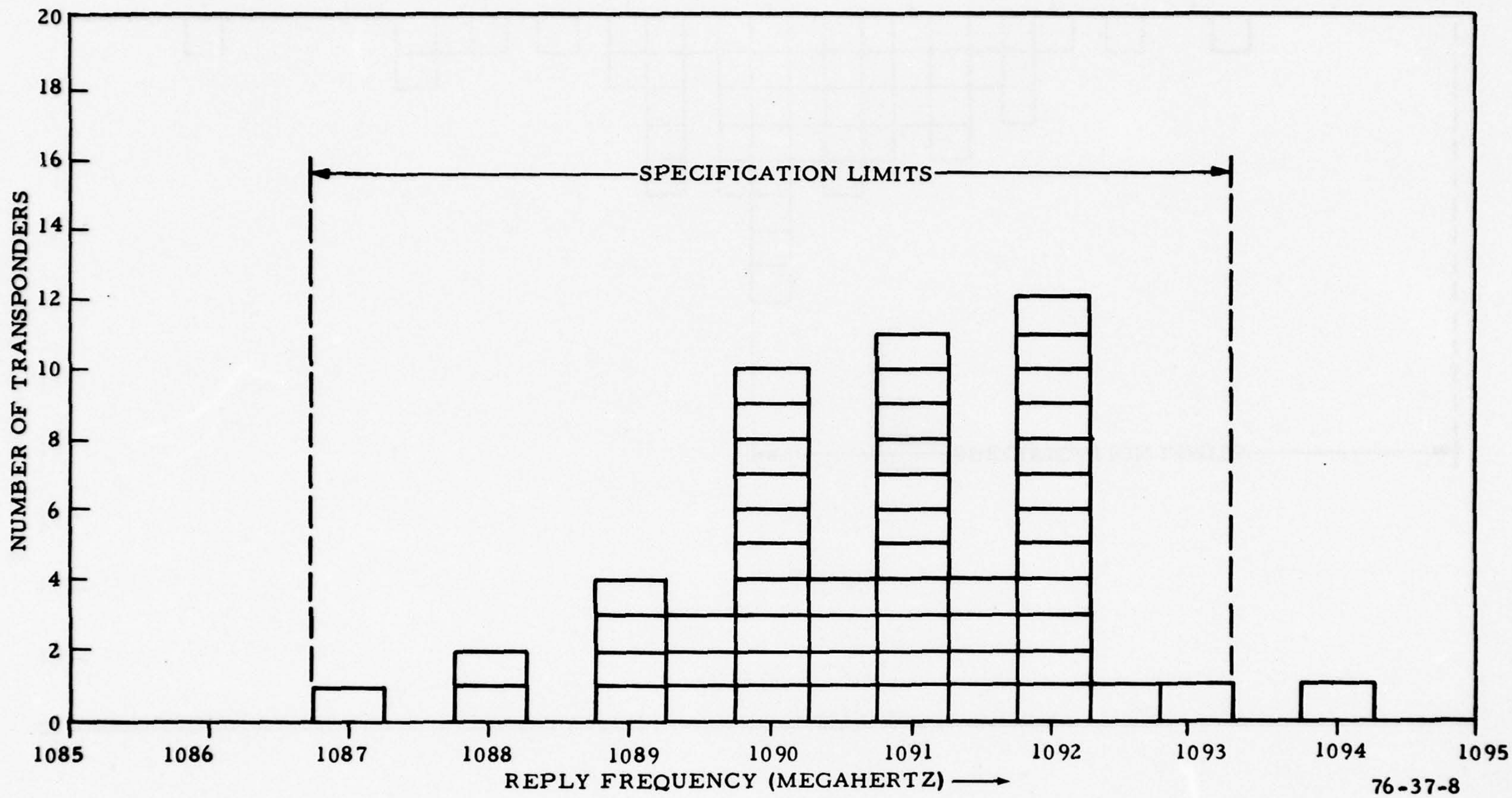


FIGURE 12. JULY 1975 TO MAY 1976 TRANSPONDER REPLY FREQUENCY VERSUS NUMBER OF UNITS

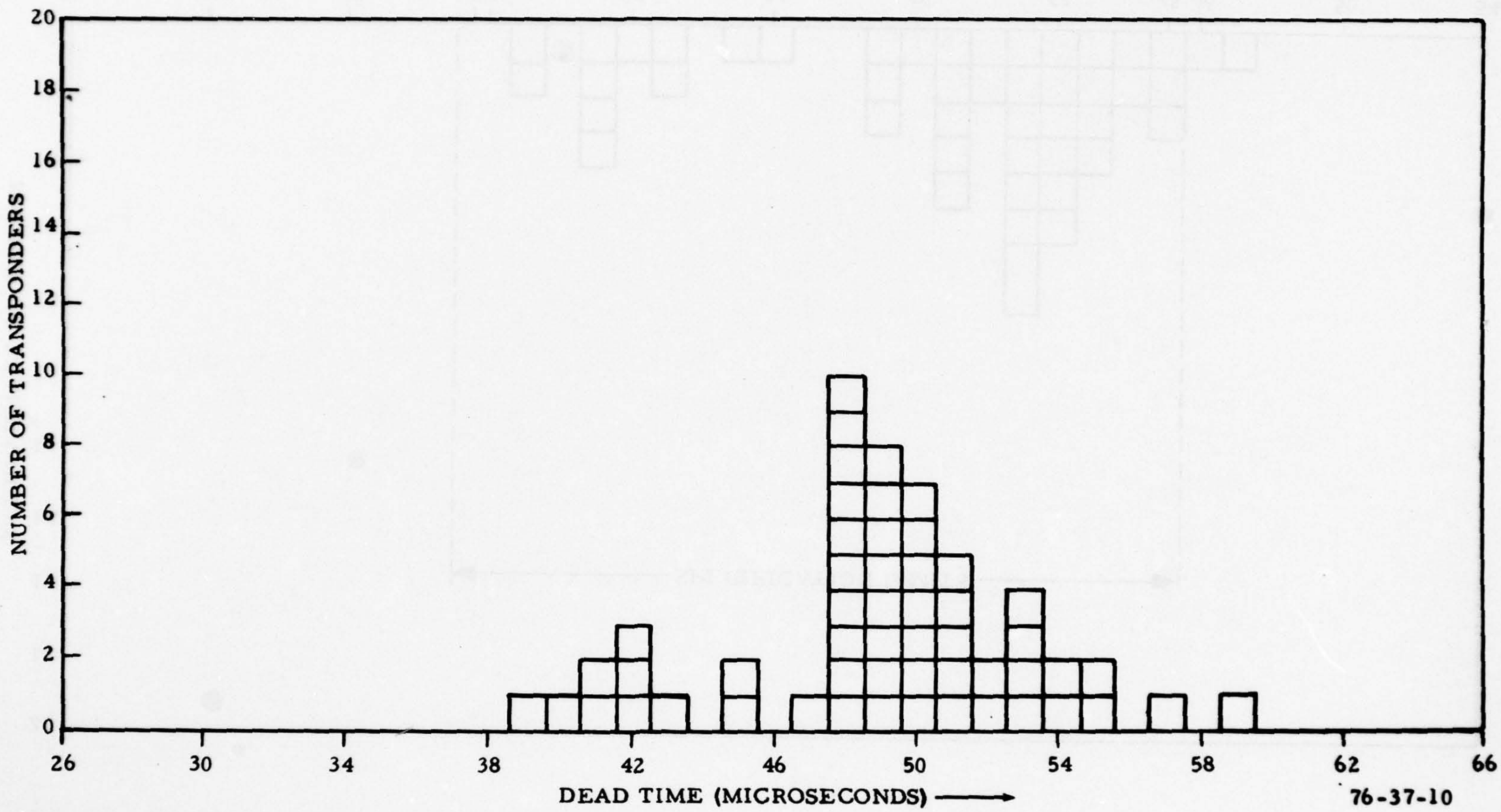


FIGURE 13. JULY 1975 TO MAY 1976 TRANSPONDER SUPPRESSION TIME VERSUS NUMBER OF UNITS

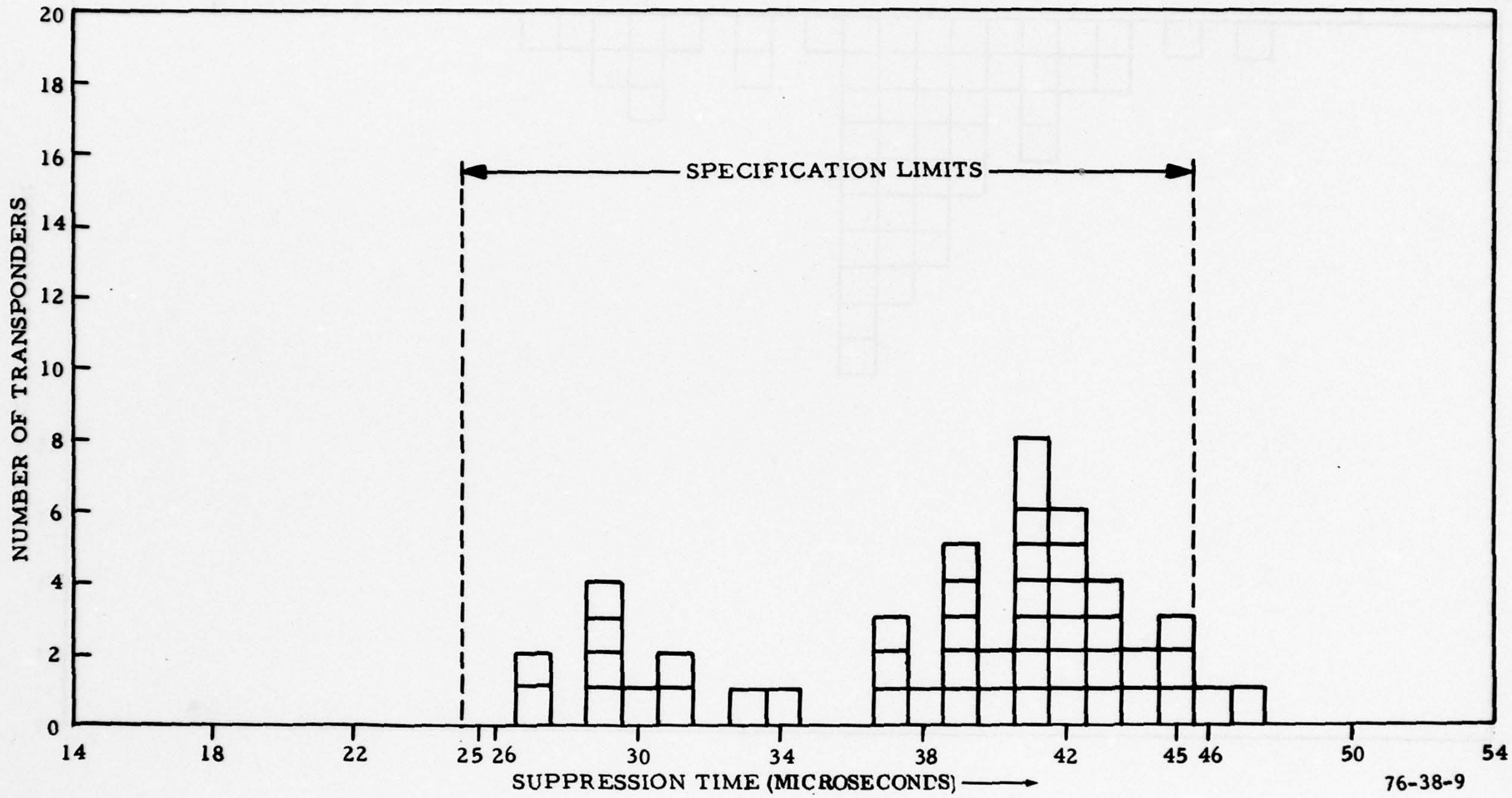


FIGURE 14. JULY 1975 TO MAY 1976 TRANSPONDER DEAD TIME VERSUS NUMBER OF UNITS

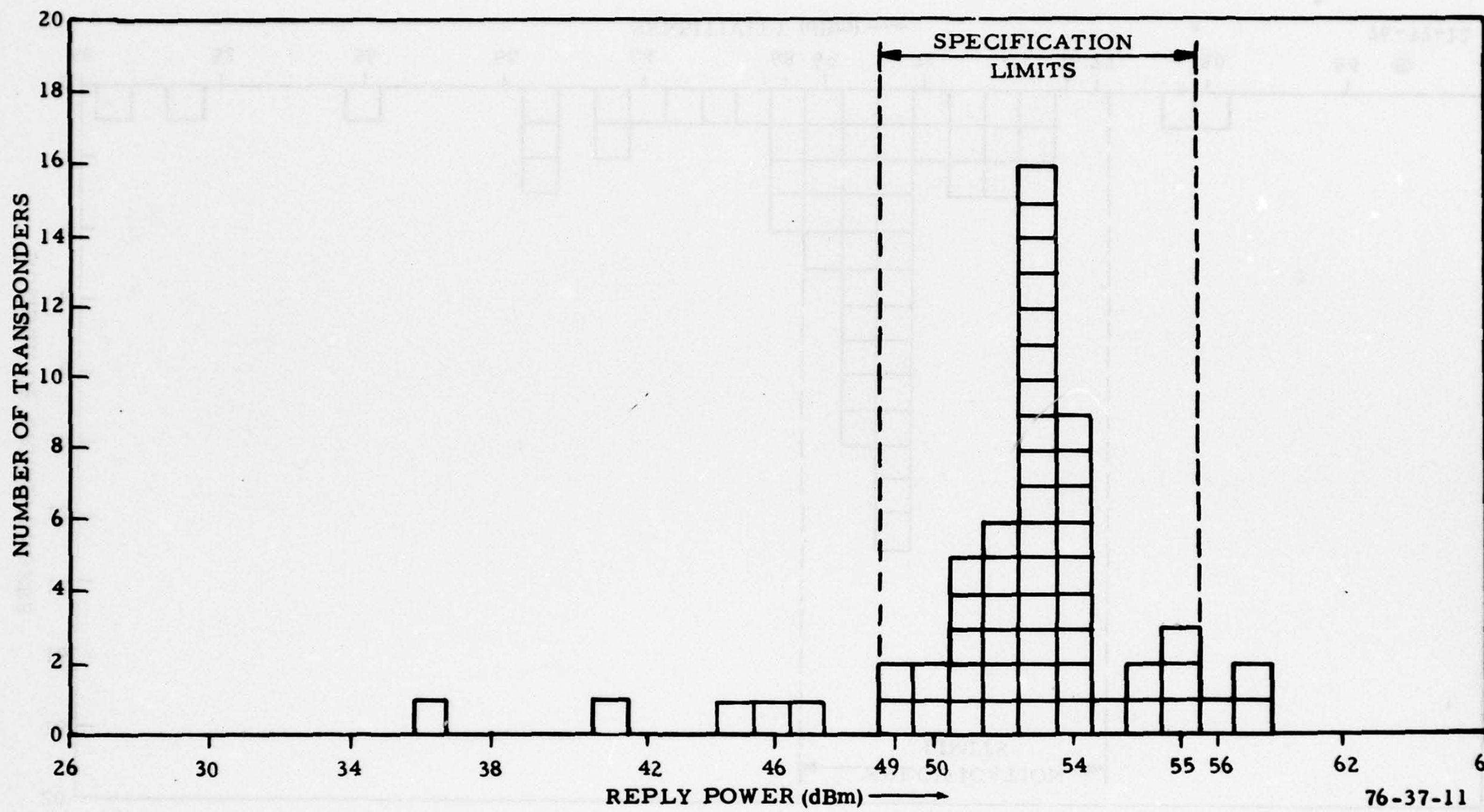


FIGURE 15. JULY 1975 TO MAY 1976 TRANSPONDER REPLY POWER VERSUS NUMBER OF UNITS

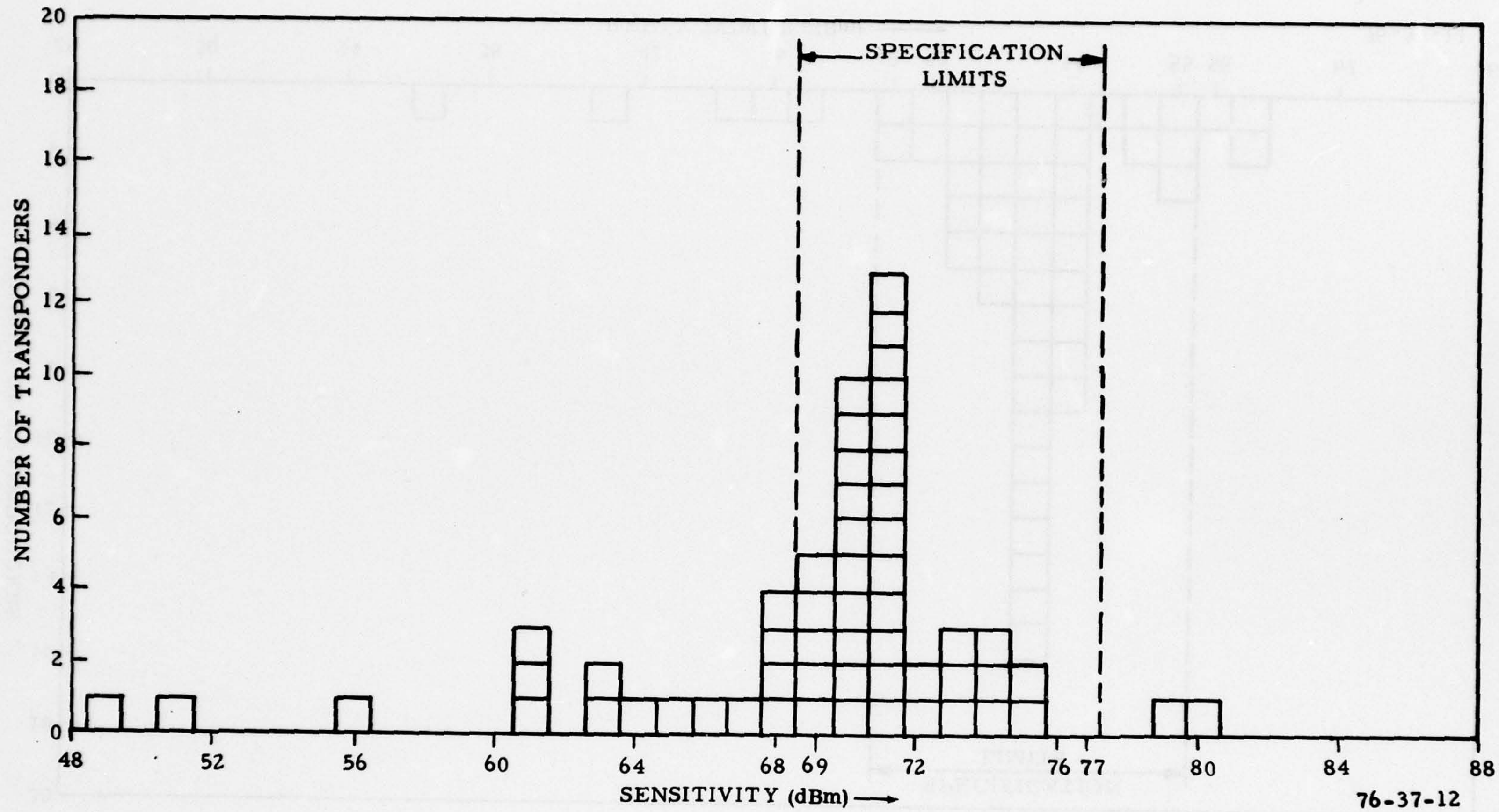


FIGURE 16. JULY 1975 TO MAY 1976 TRANSPONDER SENSITIVITY VERSUS NUMBER OF UNITS

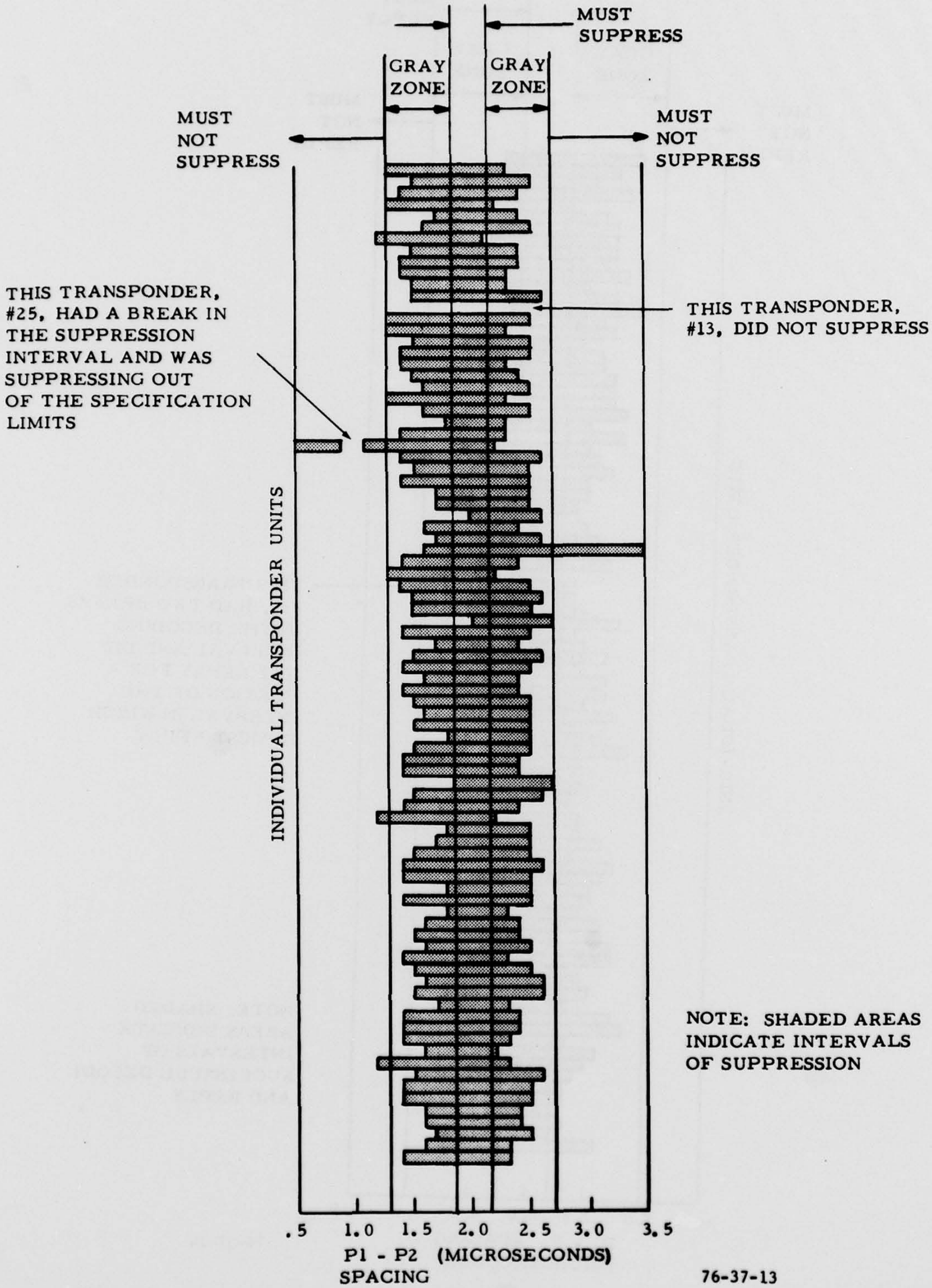


FIGURE 17. SLS DECODING ACCURACY (JUNE 1976 TO AUGUST 1976)

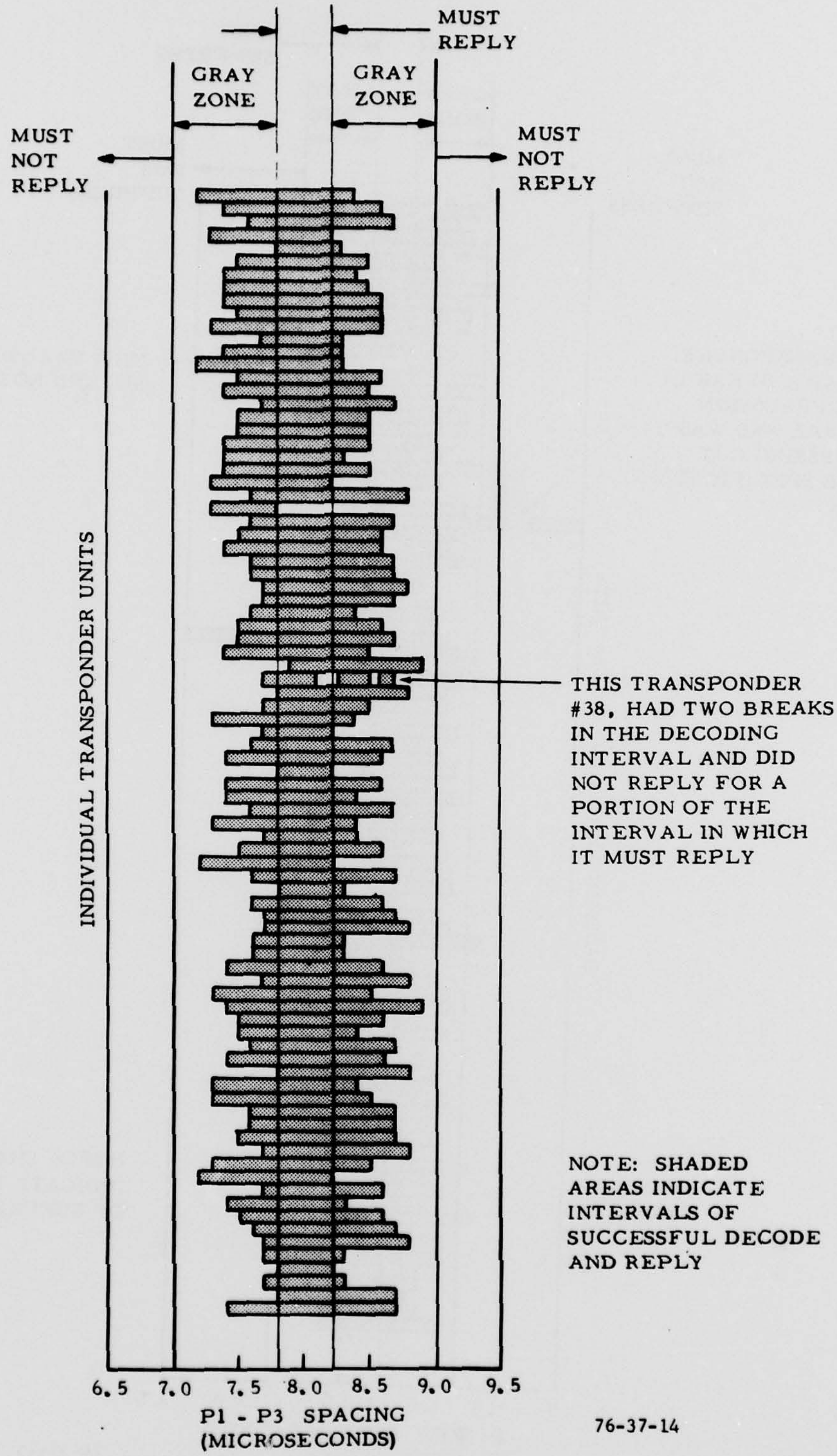


FIGURE 18. MODE 3/A DECODING ACCURACY (JUNE 1976 TO AUGUST 1976)

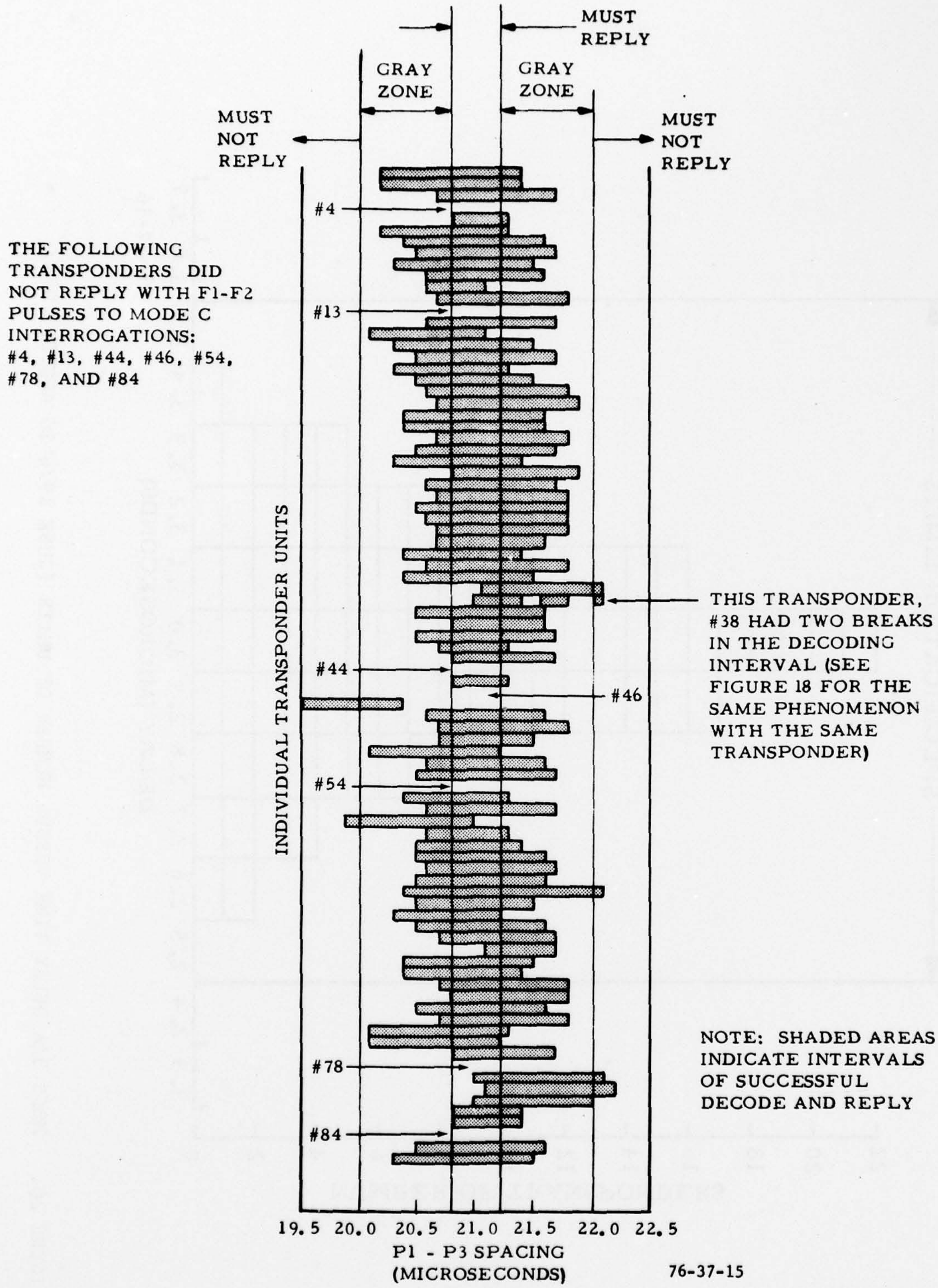


FIGURE 19. MODE C DECODING ACCURACY (JUNE 1976 TO AUGUST 1976)

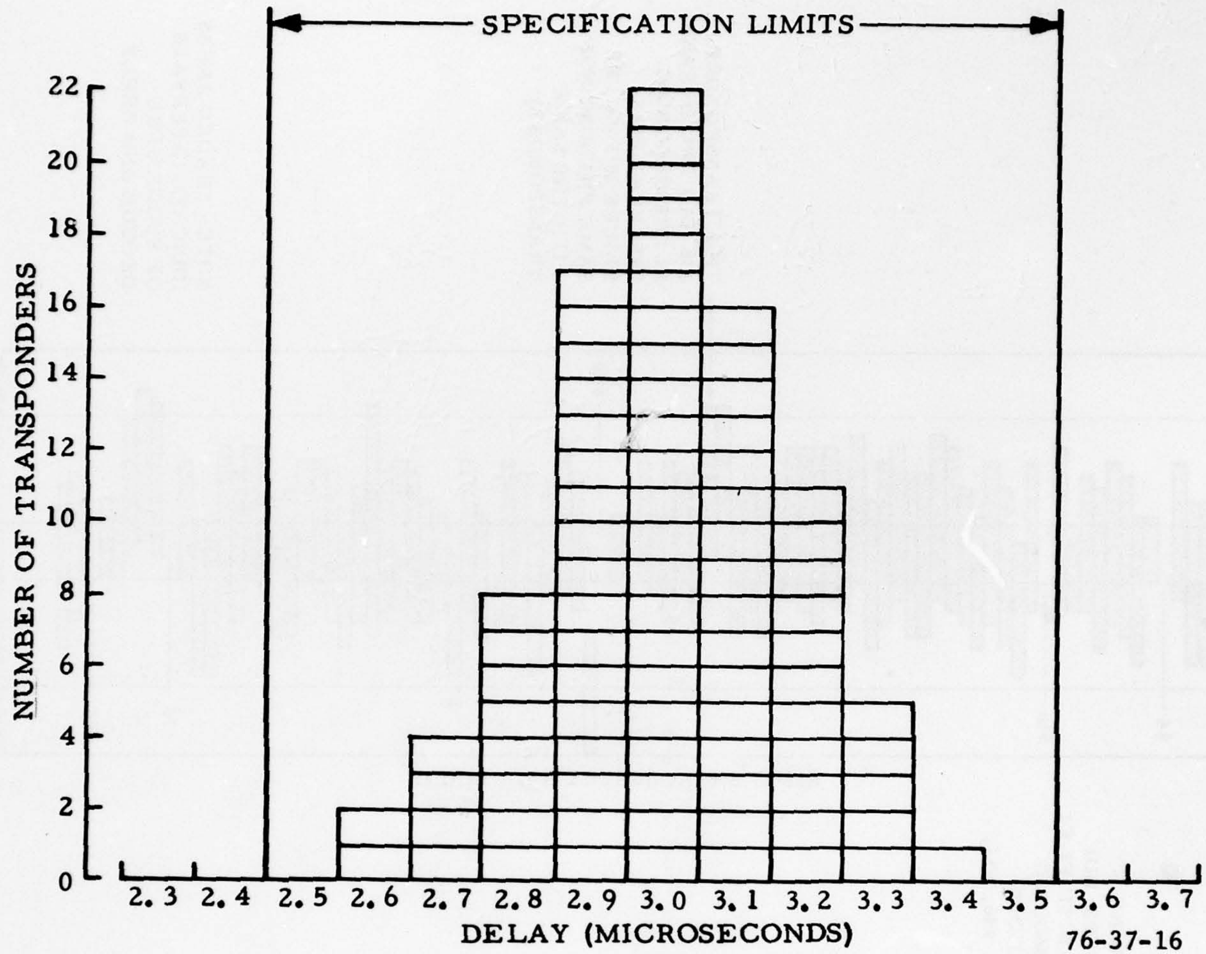


FIGURE 20. MODE 3/A DELAY TIME VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

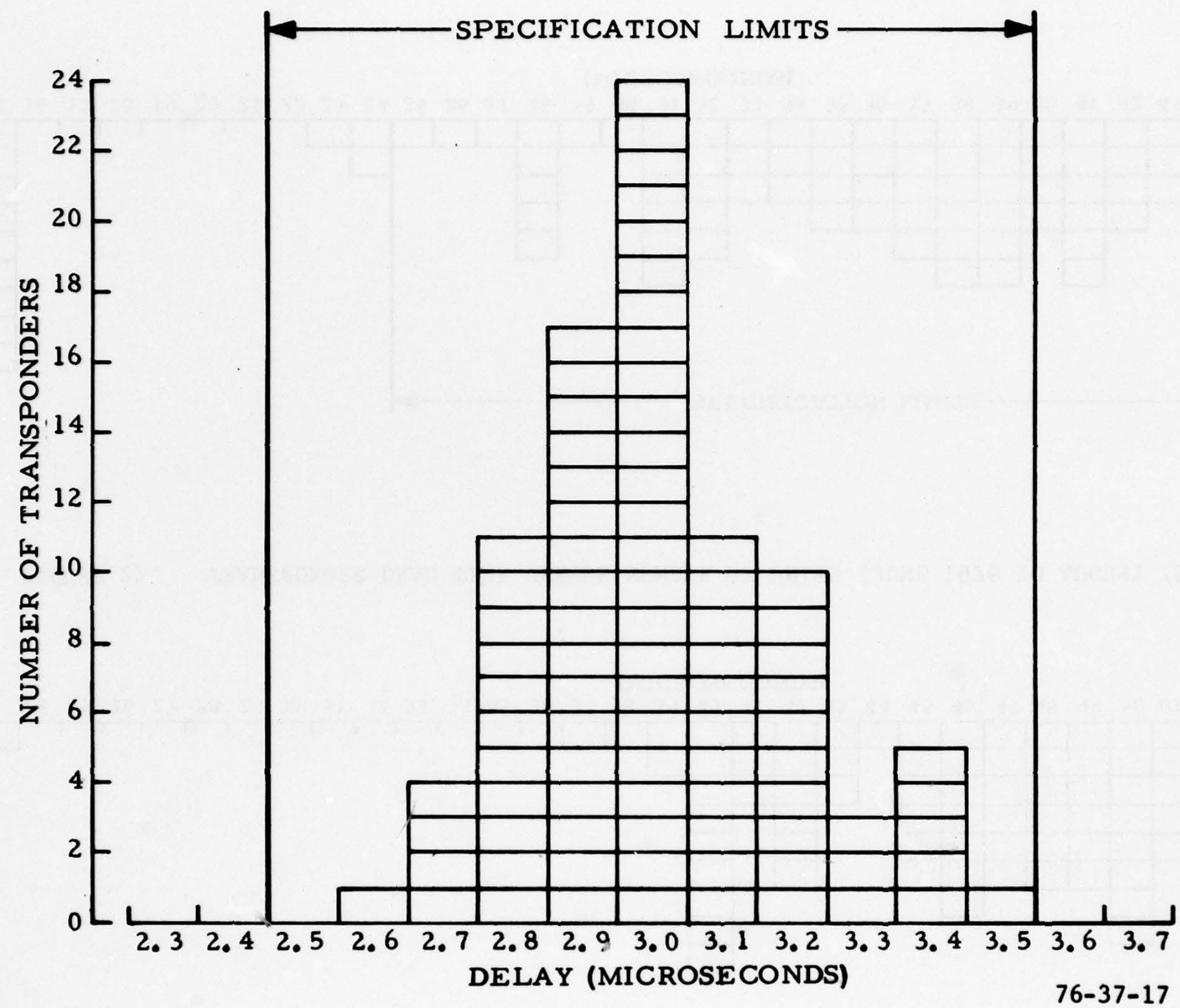


FIGURE 21. MOCE C DELAY TIME VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

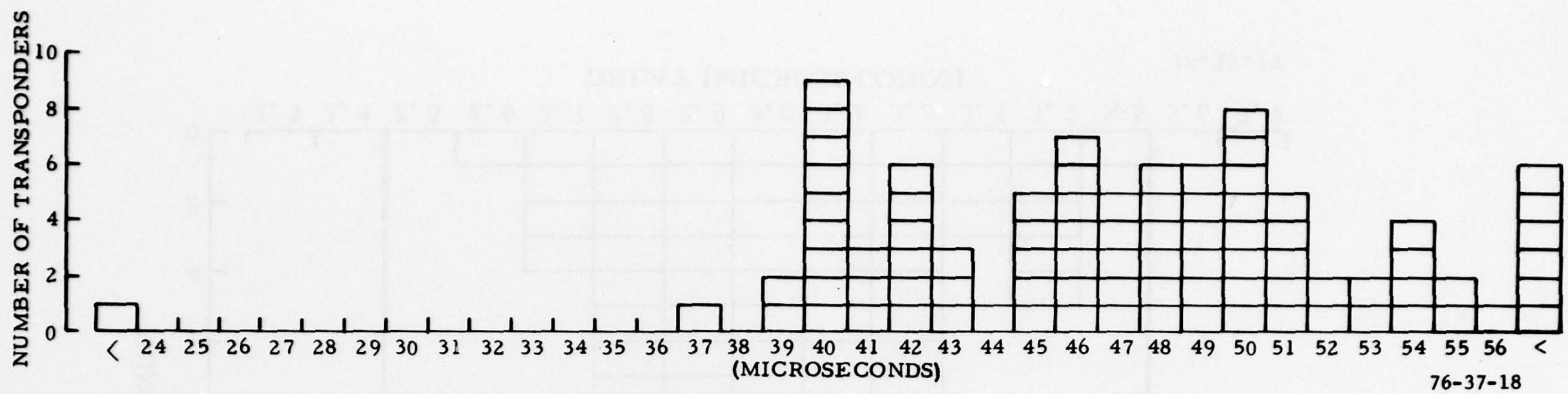


FIGURE 22. TRANSPONDER DEAD TIME VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

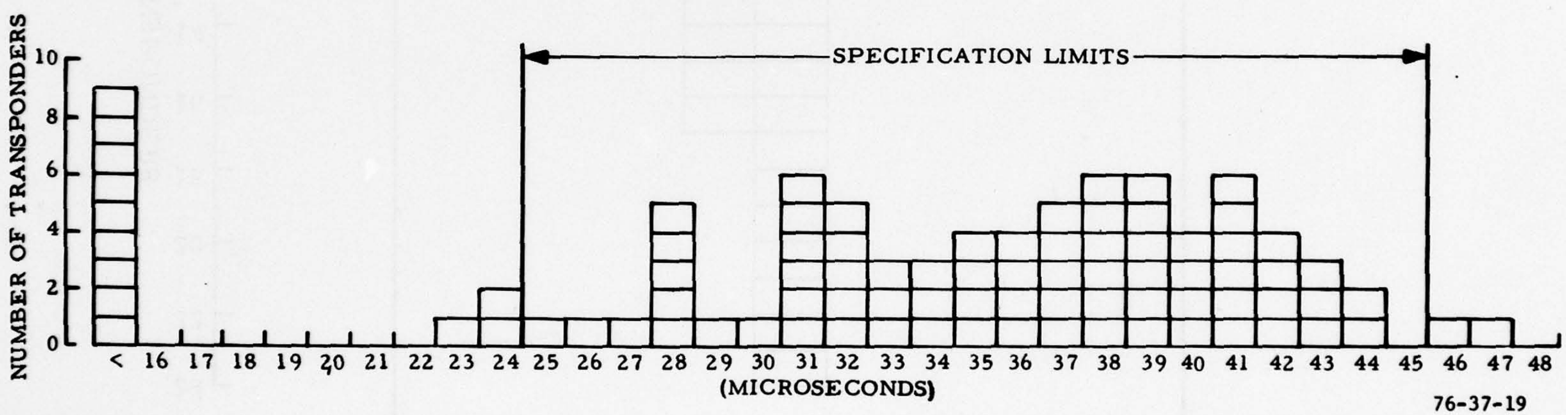


FIGURE 23. TRANSPONDER SUPPRESSION TIME VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

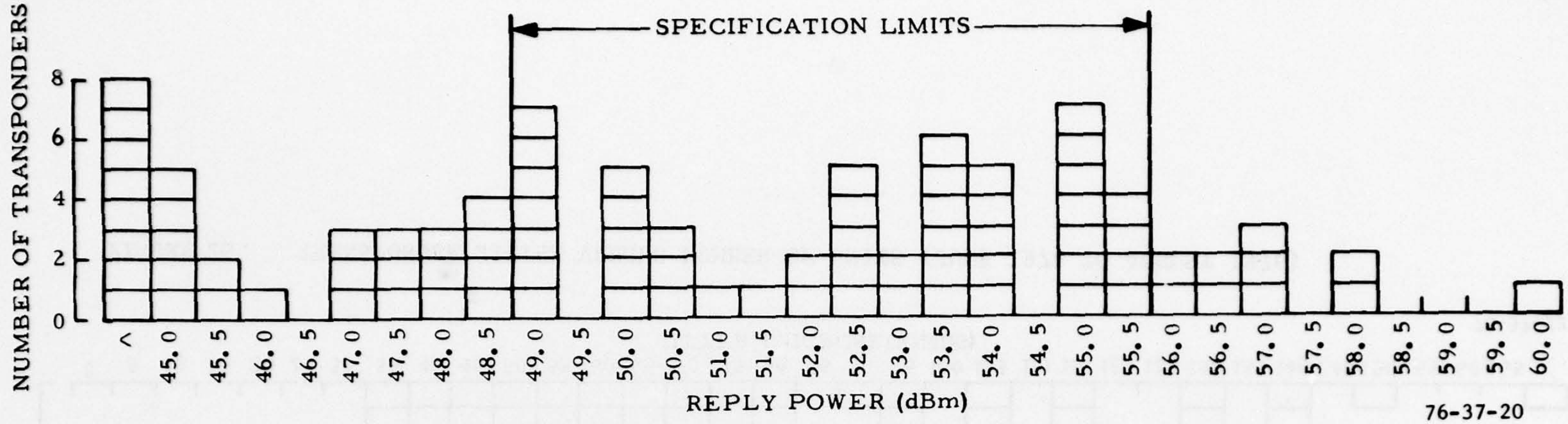


FIGURE 24. TRANSPONDER REPLY POWER VERSUS NUMBER UNITS (JUNE 1976 TO AUGUST 1976)

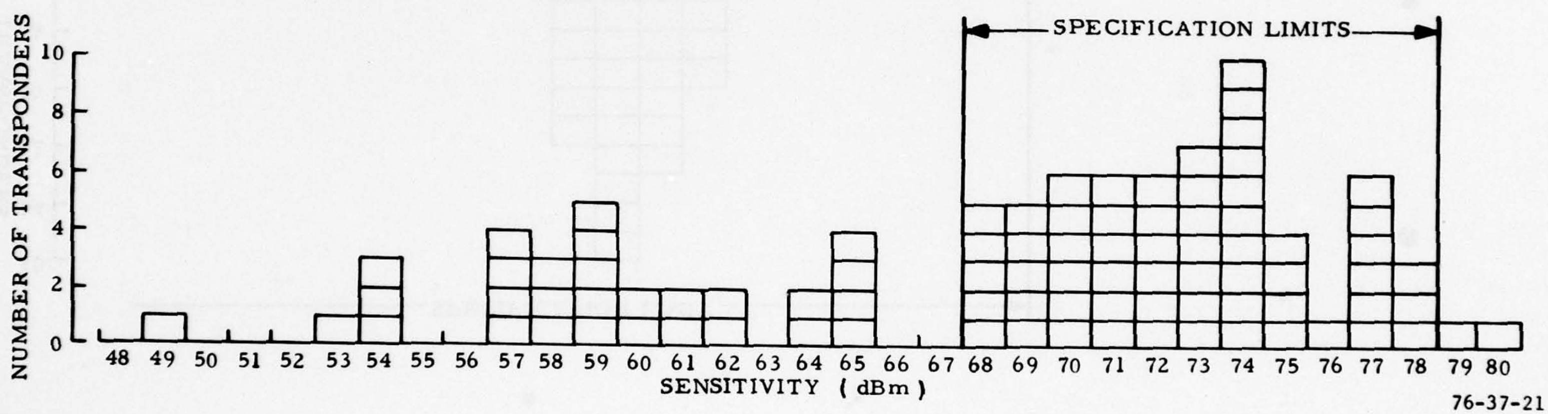


FIGURE 25. TRANSPONDER SENSITIVITY VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

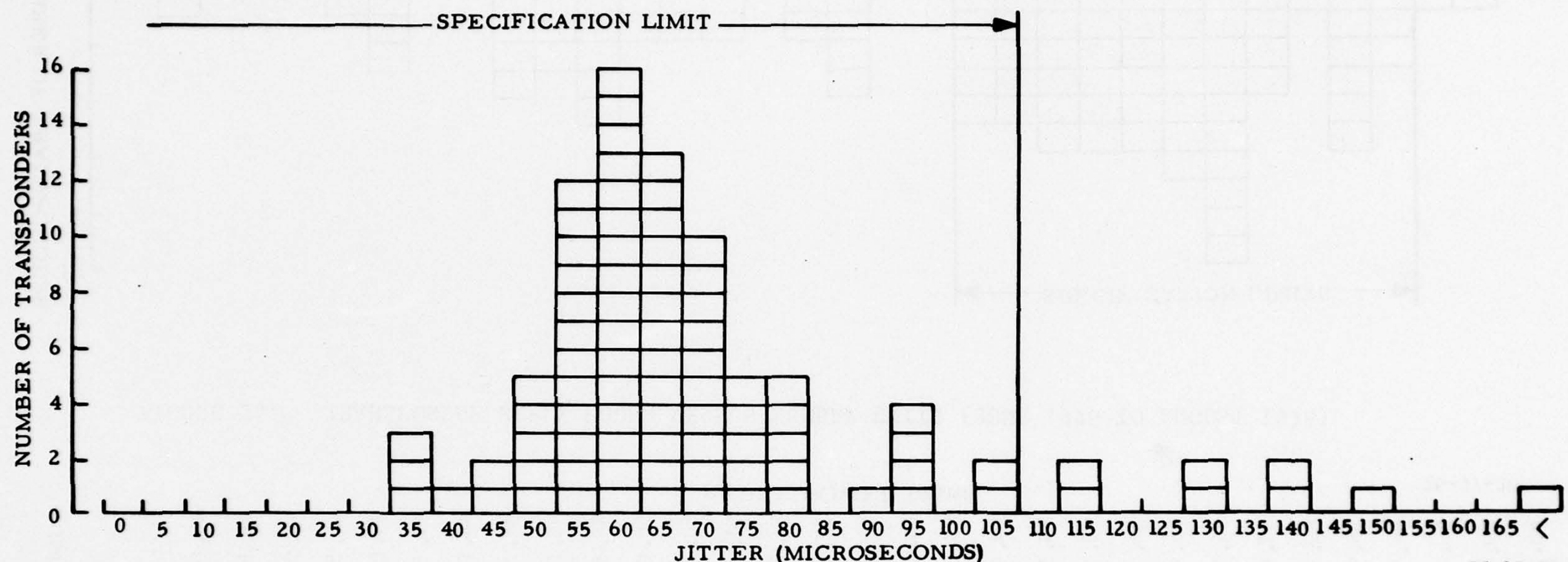


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FIGURE 26. TRANSPONDER JITTER VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

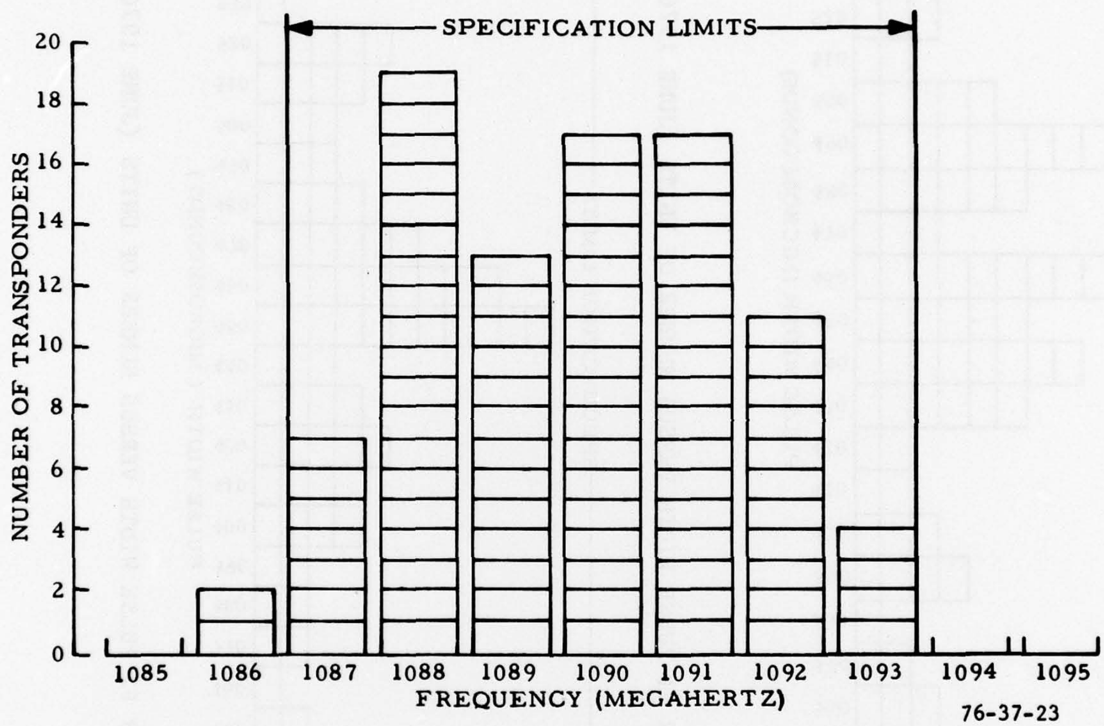

FIGURE 27. TRANSPONDER REPLY FREQUENCY VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

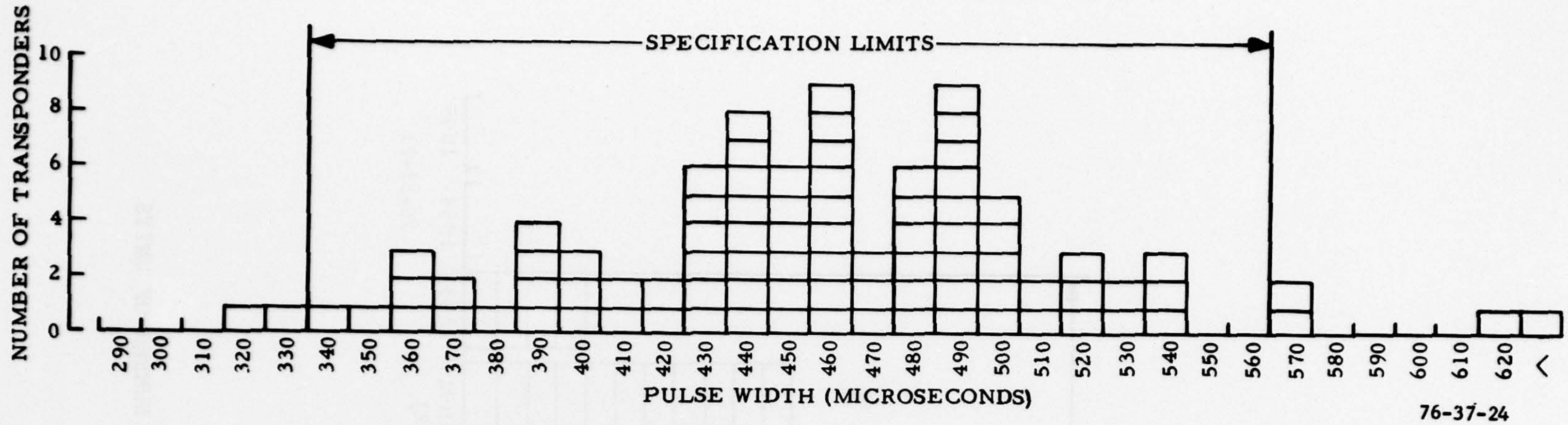

FIGURE 28. TRANSPONDER F1 PULSE WIDTH VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

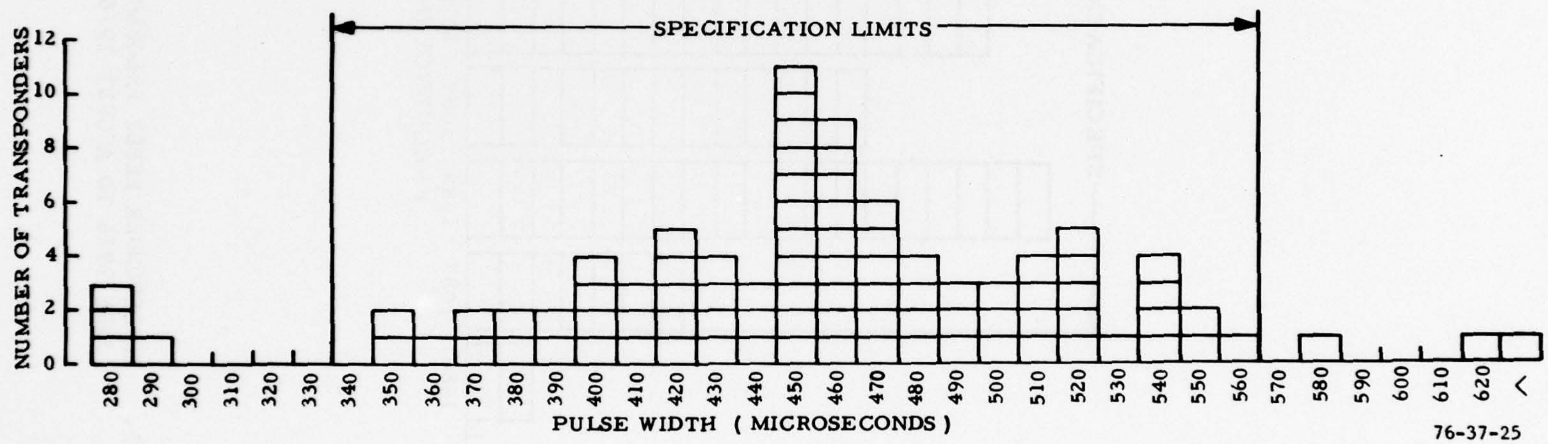

FIGURE 29. TRANSPONDER F2 PULSE WIDTH VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)

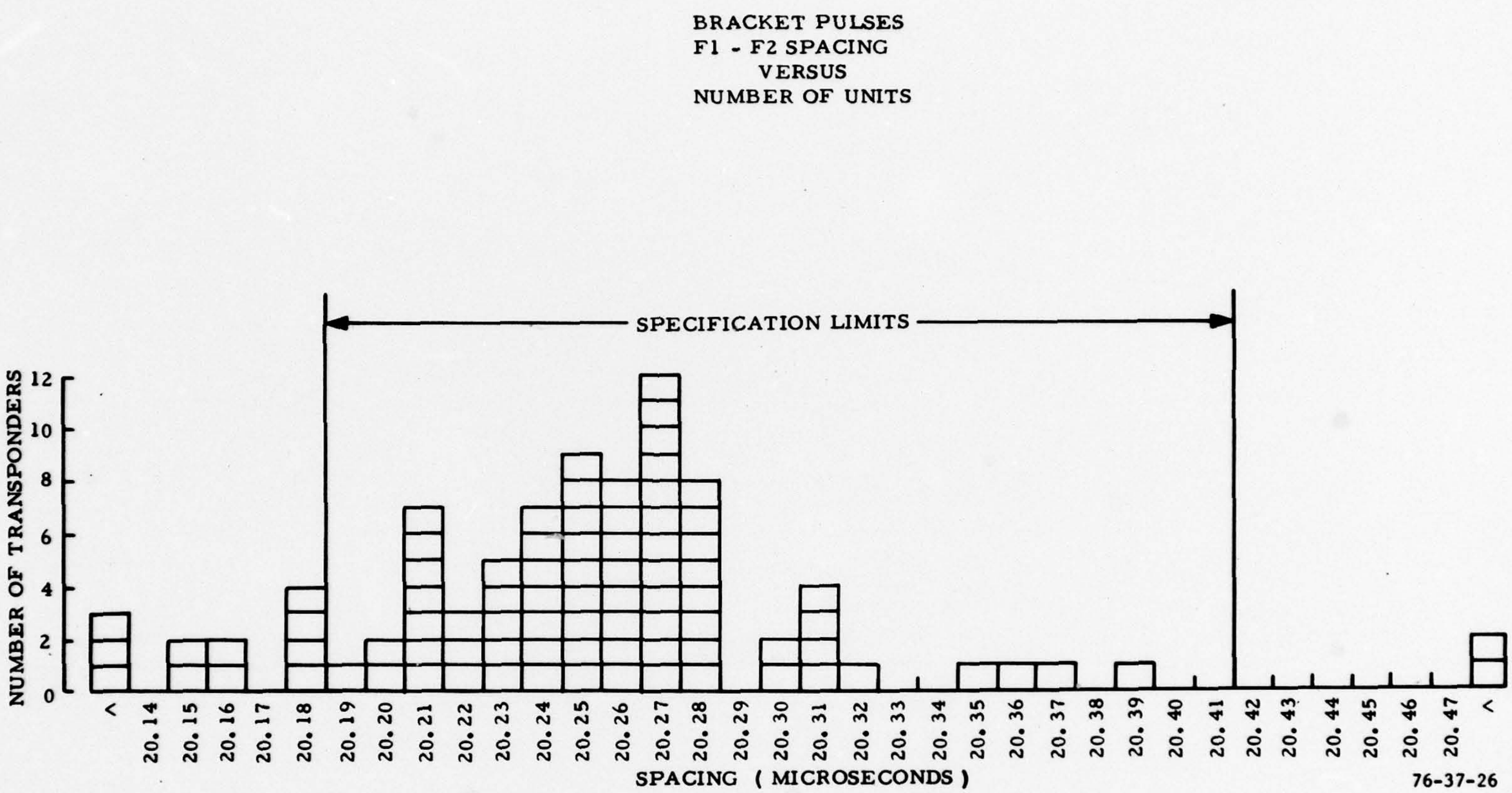

FIGURE 30. TRANSPONDER BRACKET PULSES F1-F2 SPACING VERSUS NUMBER OF UNITS (JUNE 1976 TO AUGUST 1976)